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CONTRIBUTIONS

FROM THE

BERMUDA BIOLOGICAL STATION

FOR

RESEARCH.

VOLUME I.

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CONTENTS

1. Cole, L. J. — Pycnogonida collected at Bermuda in the Summer of 1903.
   From Proceedings of the Boston Society of Natural History, Vol. 31, No. 8, pp. 315–328, pls. 20–22. July, 1904.
2. Gulick, A. — The Fossil Land Shells of Bermuda.
   From Proceedings of the Academy of Natural Sciences of Philadelphia, Vol. 56, No. 2, pp. 406–425, pl. 36. April [June], 1904.
3. Bowditch, H. — A List of Bermudian Birds seen during July and August, 1903.
   From The American Naturalist, Vol. 38, Nos. 451, 452, pp. 555–563. July–August [September], 1904.
4. Coe, W. R. — The Anatomy and Development of the Terrestrial Nemertean (Geonemertes agricola) of Bermuda.
   From Proceedings of the Boston Society of Natural History, Vol. 31, No. 10, pp. 531–570, pls. 23–25. November, 1904.
5. Bigelow, H. B. — The Shoal-Water Deposits of the Bermuda Banks.
   From Proceedings of the American Academy of Arts and Sciences, Vol. 40, No. 15, pp. 557–592, 4 maps. February, 1905.
6. Mark, E. L. — The Bermuda Islands and the Bermuda Biological Station for Research.
   From Proceedings of the American Association for the Advancement of Science, Vol. 54, pp. 471–501, 16 pls. December, 1905. *Also separate*, 32 pp., 16 pls. February, 1905.
7. Barbour, T. — Notes on Bermudian Fishes.
   From Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. 46, No. 7, pp. 107–134, 4 pls. September, 1905.
8. Blackman, M. W. — The Spermatogenesis of the Myriapods. IV. On the Karyosphere and Nucleolus in the Spermatocytes of Scolopendra subspinipes.
   From Proceedings of the American Academy of Arts and Sciences, Vol. 41, No. 13, pp. 329–343, 1 pl. September, 1905.
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10. Blackman, M. W. — The Spermatogenesis of the Myriapods. V. On the Spermatogenesis of Lithobius.
    From Proceedings of the American Academy of Arts and Sciences, Vol. 42, No. 19, pp. 487–518, 2 pls. February, 1907.

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CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL STATION
FOR RESEARCH.

No. 1.

PYCNOGONIDA COLLECTED AT BERMUDA IN THE SUMMER OF 1903.

By Leon J. Cole.

With Three Plates.

From the Proceedings of the Boston Society of Natural History,
Vol. 31, No. 8.

CAMBRIDGE, MASS., U. S. A.
July, 1904.

No. 8.— PYCNOGONIDA COLLECTED AT BERMUDA IN THE SUMMER OF 1903.[1]

BY LEON J. COLE.

THE first Pycnogonida reported from Bermuda were two species described by Professor Verrill in 1900 (Verrill, :00). The descriptions were based upon two specimens obtained by the party which with Professor Verrill visited Bermuda in 1898. During the past summer (1903), while enjoying the excellent facilities for collecting offered by the Bermuda biological station for research, special search for pycnogonids was made by the writer, and other members of the party were kind enough to turn over to him such specimens as they found.

The most noticeable fact in connection with the group was the relative scarcity both of species and of individuals. Although collections were made in a great variety of localities,— embracing the whole group of islands, the surrounding waters, and even the Challenger Bank, some fifteen miles to the southwest,— and at depths ranging from between tide marks to 35 fathoms, the only places at which Pycnogonida were found were in Harrington Sound on hydroids, and in a small 'cut' connecting the Sound with Flatts Inlet. Altogether only three species were obtained. Professor Verrill's specimens were taken, one in Flatts Inlet, and one in Bailey's Bay; the other specimens which I have examined, to be mentioned later, had no more definite indication of locality than 'Bermuda.' As stated above, all the specimens collected this year were found on hydroids, and as hydroids are relatively scarce, a corresponding paucity of Pycnogonida might be expected. That none were found on the hydroids collected in Castle Harbor, where conditions are similar in some respects to those in Harrington Sound, may in part be explained by the fact that less careful search was made in that region than in the Sound and at the Flatts, where the laboratory was situated; for all three of the forms are so inconspicuous — two on account of their small size and one on account of its protective coloration — that they are apt to be overlooked unless unusual attention is given to hunting for them.

---

[1] Contributions from the Bermuda biological station for research. No. 1.

The 'cut' mentioned above (B. B. S. station 1403) deserves special mention. This is an artificial channel made in the limestone rock, three feet or so wide, and extending in a straight line through a narrow neck of land between Harrington Sound and the Flatts Inlet. The tides rush through this 'cut,' alternately in and out, with great swiftness, and collecting is feasible only at or near the ebb, when the water is barely two to three feet deep. Direct sunlight is almost entirely excluded, owing to the high vertical sides of the canal and the overhanging vegetation. Here in the half-light such animals as sponges, especially the brightly colored, encrusting forms, bryozoans, and hydroids grow in the greatest abundance. All but two of the Pycnogonida collected this year came from among the hydroids at this place, where they are associated with Caprella, which occurs in large numbers.

The conditions found here suggest an interesting problem in the etiology of these animals. With the tide almost constantly sweeping through, one way or the other, how is it that the pycnogonids remain abundant; why is it that they are not all swept away? The adults, it is true, cling tenaciously by their feet, which can clasp a small hydroid stem or similar object very efficiently when the claw is bent back against the sole. This is especially the case when the heel, with its distally projecting strong spines, is developed. But the danger comes to the eggs and the larvae. In the case of sponges and similar organisms which produce large quantities of young, these, although set free into the water, are so abundant that the stream passing through is sure to contain many of them; some of these probably become lodged in the 'cut' and attach themselves there, so that the place remains stocked. But pycnogonids produce relatively few eggs. If these were set free, the chances are that they would be carried away and very few, if any, would find lodgment in the 'cut'; but as a matter of fact the eggs are taken directly from the female by the male (*cf.* Cole, :01, p. 204) and are carried by him until they are hatched. The newly hatched larva of Ammothea and related forms bears a large pair of chelae on the enormously developed chelifori, by which it is enabled to cling to the parent, or to hydroids and similar objects. The other appendages at this time are of no use in this connection. After the metamorphosis, in which the legs with grasping claws are attained, the chelifori are not needed for the purpose of clinging, and in the adult the fingers of the chelae are lost completely, the organ probably becoming entirely functionless as well as degenerate in form.

While I believe this may serve as an explanation of the loss of the chelae in the adult Ammothea, we have a different state of affairs in Anoplodactylus, which is found associated with it in the 'cut,' for the latter retains its chelae throughout the adult condition. In some cases at least it would seem that they are probably not needed for attachment even by the larva, which is parasitic in the gastral cavity of certain hydroids (*cf.* Dohrn, '81, pl. 12, fig. 25, who shows three larvae of *A.* [= *Phoxichilidium*] *exiguus* in the interior of a polyp of *Podocoryne carnea*); but in the larvae of *A. plumulariae* (von Lendenfeld) Cole, although they are parasitic, the chelifori are strongly developed and are used for clinging to the hydroids, into which the proboscis is thrust in order to obtain nourishment (von Lendenfeld, '83). In the adult Anoplodactylus they are probably not used at all for clinging; but it seems more probable that in these forms they are retained for some function which they perform in connection with feeding, for they are always elongate and the chelae hang down over the proboscis in close proximity to the mouth (pl. 22, figs. 21, 29).

Professor Verrill has very kindly allowed me to examine the types of his two species, and this has been of great assistance in writing the present report. He has also placed in my hands for study three specimens which his party collected at Bermuda, in 1901, and three others obtained by G. Brown Goode, in 1876–77. All of these belong to the two species found by Verrill in 1898. Some further notes and descriptions of these species are given below, together with the addition of a new form, which, however, so closely resembles *Anoplodactylus insignis* (Hoek) that I have placed it as subordinate to that species. The typical *insignis* is known from but a single specimen dredged by the 'Challenger' at Bahia, South America.

Ammothea gracilis (Verrill).

Pl. 21, fig. 4–14.

Achelia (?) *gracilis* Verrill, :00, p. 582, pl. 70, fig. 10.

This species, which seems to be well founded, is so briefly described by Verrill,— who had but a single specimen,— that I venture to give a fuller description based upon the considerable amount of material at my disposal.

Trunk broad, not tapering markedly posteriorly; anterior border with a rather elongate conical tubercle, tipped with a short spine at each side of the eye tubercle; segmentation suppressed. Lateral processes closely appressed, larger distally, their outer ends giving a broadly elliptical outline to the body; nearly unarmed, but the first pair may bear one or two tubercles similar to those on the anterior border of the trunk.

Caudal segment short, slightly elevated, barely reaching to posterior edge of first coxal joint of fourth pair of legs; not marked off from trunk by a distinct suture; tapering more or less evenly, or slightly fusiform; slightly bilobed at tip. Armed with a short spine on each side at a little distance from the tip.

Eye tubercle situated at extreme anterior end of trunk, low, obtusely conical or dome-shaped, directed somewhat anteriorly when seen from the side (pl. 21, fig. 5); seen from in front or from behind (pl. 21, fig. 13) it is obtuse at the tip owing to a small projection on each side. Eyes moderately large, dark brown.

Proboscis rather long, about equal in length to trunk (pl. 21, fig. 5), but arising so far under the first trunk segment that when viewed from above much of its base is hidden and it has the appearance of being much shorter than it really is, and of being evenly tapering (pl. 21, fig. 4). In reality it is fusiform, being broadest at its proximal third, and tapering in both directions from this point. Its dorsal curvature is considerably more convex than the ventral outline. There is no evidence of the circular constriction which is found in several species of this genus.

Chelifori short, scarcely equaling a fourth of the proboscis; also arising from beneath the anterior edge of the trunk, so that when seen from above they appear even shorter than they really are. Basal joint about twice as long as broad, bowed slightly outward, somewhat larger distally; second segment small, globular, with a distinct dorso-ventral groove dividing the distal part into two subequal lobes, which are the vestiges of larval chelae. The chelifori bear a few very small scattering spines, and there is a slightly larger one constantly on the outer side of the larger lobe of the second joint.

Palpi 7-jointed; *j.* 1[1] short, broad; *j.* 2 at least twice as long, slightly arcuate; *j.* 3 short; *j.* 4 nearly as long as *j.* 2, dorsal margin irregular; *j.* 5 smaller than *j.* 3; *j.* 6 longer than *j.* 3 but shorter than *j.* 4; *j.* 7 small, globose or slightly elongate. Joint 7 and the ventral sides of *jj.* 5 and 6 closely beset with short spines; otherwise the appendage is almost smooth. The palp is bent down at *i.* 3 and forward again at *j.* 5, so that it is Z-shaped.

Ovigera 10-jointed in both sexes. Oviger of female slightly shorter than fully extended palp; *jj.* 1, 2, and 3, short, little if any longer than broad, *j.* 2 arising somewhat from the side of *j.* 1; *jj.* 4 and 5 about equal in length, longer than the preceding joints; *jj.* 6, 7, 8, and 9 of nearly equal size, and smaller than the basal joints; *j.* 10 minute, but bearing two rather long, curved denticulate spines. Joints 7, 8, and 9 each bear two denticulate spines; otherwise the appendage is practically unarmed. Oviger of the male longer than that of the female and longer than the palp; relative proportions of the joints about the same as in the female; *j.* 10 very small, but slightly larger than in the female and similarly bearing two long, curved, denticulate spines, which bend back in such a way as to form a hook. Denticulate spines were also distinguished on *jj.* 9 and 8, but could not be discerned on more proximal joints. The principal flexure of the oviger is between *j.* 4 and *j.* 5, which is practically the middle point in the length of the appendage; the distal portion is curved sigmoidally.

Egg masses few, globular, loose. The specimens carrying eggs had only one or two masses each. The eggs are relatively large, but the masses are of moderate size, there being comparatively few eggs in each mass. Eleven of the 29 adult males examined were carrying eggs. Ova could be distinguished in the ovaries of many of the females.

Legs about twice as long as body; *c.* 1, *c.* 2, and *c.* 3 all short; *c.* 2 only a little longer than *c.* 1 and *c.* 3; *f.* slightly longer than coxal region; *t.* 1 and *t.* 2 each about the length of *f.*; *ts.* 1 short, triangular, emarginate at distal border; *ts.* 2 rather slender for this genus, somewhat more than half as long as *t.* 2, only slightly arcuate, projection at the distal end slight, no differentiation into heel and sole except in the size of the spines on these two regions; *cl.* strong, curved, half as long as *ts.* 2; *aux. cl.* well developed, fully half as long as *cl.* The femoral joint of the female is broader than that of the male, and is broadest near the middle (pl. 21, fig. 4), while in the male it is broadest distally (pl. 21, fig. 14); in both sexes the dorso-distal corner projects and is armed with a spine. The margins of *f.*, *t.* 1, and *t.* 2 are more or less irregular and wavy. The first and second coxal joints of the male are armed with prominent tubercles bearing spines (pl. 21, fig. 14), three of these regularly occurring distally on the dorsal side of *c.* 1, and one or two laterally on *c.* 2; in the female these tubercles are much reduced, the two lateral ones at the distal end of *c.* 1 being best represented, while the middle tubercle is low and does not bear a spine (pl. 21, fig. 4). The remaining joints of the legs are but sparsely armed with short spines, but have longer ones in the usual positions, *i. e.*, one near the distal end on the dorsal margin of each *t.* 1 and *t.* 2, and on the dorsal margin of *ts.* 2. The ventral surface of *ts.* 2 bears a number (about 7 to 10) of comparatively stout spines, those on the proximal end being somewhat longer and representing the only indication of a heel; *ts.* 1 bears one strong spine and several small ones. The genital protuberance on the ventral side of *c.* 2 of the third and fourth pairs of legs in the male is short, conical, and unarmed (pl. 21, fig. 11); genital openings of the female, as usual in the genus, not on protuberances, but in a corresponding position on all four pairs of legs.

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[1] The abbreviations used here are those which I have employed in another paper (Cole, :**04**). They are so obvious that they hardly need explanation. In those appendages in which the joints do not have special names, the first proximal joint is designated as *j.* 1, the second *j.* 2, and so on. In the case of the legs, *c.*1, *c.*2, *c.*3, *f.*, *t.*1, *t.*2, *ts.*1, *ts.*2, *cl.*, and *aux. cl.* refer to the coxal, femoral, tibial, and tarsal joints respectively, and to the terminal claw and the auxiliary claws.

Length about 1.3 mm., extent nearly 6 mm. The males average slightly smaller than the females.

Color nearly white. Integument thin, with comparatively few cuticular cavities.

Immature specimens. — The four immature specimens examined were of nearly adult size, but the ovigera were not yet fully developed and the chelifori were still in a chelate condition (pl. 21, fig. 12). The fingers of the chelae are about as long as the palm; strongly arcuate, the movable finger slightly overlapping the other. This is probably the stage immediately preceding the last moult before the adult condition is attained.

All the specimens of this species taken this year were found on colonies of *Eudendrium ramosum* (Linn.) and *Obelia marginata* Allman.[1] The specimens collected by Dr. Goode in 1876–77 were found "on Crissa."

Specimens examined.

Locality.	No. of specimens.	Date.	Source.
Harrington Sound . (B. B. S. sta., 708)	1 ♂	7 July, 1903	(Coll. by O. Bryant)
Harrington Sound . (B. B. S. sta., 708)	1 ♀	11 July, 1903	(Coll. by O. Bryant)
Flatts Inlet. . . . (B. B. S. sta., 1403)	18 ♂, 10 ♀	17 July, 1903	(Coll. by L. J. C.)
Flatts Inlet. . . . (B. B. S. sta., 1403)	2 ♀	18 July, 1903	(Coll. by L. J. C.)
Flatts Inlet. . . . (B. B. S. sta., 1403)	7 ♂, 6 ♀, 2 juv.	28 July, 1903	(Coll. by L. J. C.)
'Bermuda' . . .	1 ♂, 2 juv.	1876–77	Yale univ. museum, No. 3361 (G. Brown Goode)
'Bermuda' . . .	1 ♂	1901	Yale univ. museum, No. 3363 (A. E. Verrill)
'Bermuda' . . .	1 ♂	1901	Yale univ. museum, No. 3364 (W. T. VanName)
'Bermuda' . . .	1 ♀[2]	1898	(A. E. Verrill)

It will be noticed that the description given above differs in several important features from that of Verrill. According to his description the palpi are "apparently 8-jointed or perhaps 9-jointed." While I have not counted them on all of the specimens given in the above list, I have done so on a large number, and in all cases have found these appendages to be 7-jointed, with one exception. This was a female which had one palp 7-jointed, while the other was composed of but six joints. From the fact that all the joints up to and including the fifth were of normal size, and that the sixth was very small, it seems not improbable that this was a case in which the palp had previously been broken off between the fifth and sixth joints and was in process of regeneration. Owing to the position in which the palp is carried, and the irregular outline of the fourth joint, it is often very difficult to make out the joints with certainty when viewed from above in a specimen mounted on a slide, as the appendage does not lie out flat. In such cases the only safe method is to get the palp into such a position that it may be seen laterally; then the presence of a complete ring in the chitin and the arrangement of muscles inside gives the certain criterion of a joint. It is probable that Professor Verrill mistook the appearance in the fourth joint for an articulation, and so counted eight joints instead of seven.

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[1] I am indebted to Mr. E. D. Congdon for the identification of these hydroids.

[2] Type of the species, loaned by Professor Verrill for comparison. This specimen was from "Flatts Inlet, dredged in shallow water."

A form with 7-jointed palpi would not come in the genus Ammothea as heretofore defined, since this included only those species with eight or nine joints in the palpi, nor would it be embraced in the genus as recently restricted by me (Cole, :**04**, p. 262) to forms with only eight joints. It seems, however, that the species under discussion so closely resembles typical Ammothea that it should properly be placed in that genus, which would then include forms with seven or eight joints in the palpi. According to Leach ('**14**, p. 33) the species (*A. carolinensis*) upon which he based the original description of the genus had 9-jointed palpi; but on the other hand he states that the chelifori ('mandibles') are 2-jointed, and distinctly so figures them. In dividing the genus it thus became a question in which group *carolinensis* really belonged, and which group should therefore retain the original name. Several reasons have led me to retain in the genus Ammothea the species with 2-jointed chelifori and 8-jointed palpi and to place those with 3-jointed chelifori and 9-jointed palpi in a distinct genus, Ammothella. In the first place, although it is possible that Leach's specimen may represent an intermediate form, the differences are so constant in those species which are well known that it seems more probable he has made a miscount of the joints of the palpi — a matter which may happen at times, as mentioned above. The character of the chelifori seems much more reliable and these he distinctly describes and figures with two joints. Furthermore, the next forms which were referred to the genus are well known species with 2-jointed chelifori and 8-jointed palpi (*cf.* Hodge, '**46**); and, finally, the species with which the name Ammothella was first used, is one in which the chelifori have three joints and the palpi nine joints.

As has been pointed out in other places, the name Achelia used by Verrill is not tenable, as the forms described under it were merely the adults of Ammothea.

Ammothella appendiculata (Dohrn).

Pl. **21**, fig. 15–18; pl. **22**, figs. 19, 20.

Ammothea appendiculata Dohrn, **'81**, p. 152–155, pl. 7, fig. 1–5.
Ammothea (?) [subgenus *Ammothella*] *rugulosa* Verrill, **:00**, p. 581, pl. 70, fig. 9.

Although Verrill describes this species as new, I am unable, after comparison with the excellent description of *A. appendiculata* given by Dohrn, to separate it from that species. The greatest discrepancy is in the statement that the palpi are 10-jointed. Verrill in his description of the Bermuda form also gives ten as the number of the joints in the palpi. While I hesitate to question the observations of two such eminent naturalists, nevertheless I am certain from my study of the specimens collected at Bermuda this summer and of Professor Verrill's type that these have but nine joints in the palpi; and since it is easy for one to miscount in these cases, as I have shown above, it seems to me not unlikely, considering the close agreement in other respects, that Dr. Dohrn may also have made out one too many joints in these much abused appendages. When I first examined the specimen which Professor Verrill so generously placed at my service, I also counted ten joints, but having previously made drawings from palpi of this species mounted separately on slides so that they lay out flat, and having distinguished but nine joints, I examined the specimen more critically and found that what I had counted as joints four and five was in reality only one joint, as there was neither a complete chitinous constriction nor were there muscles at this place (see pl. 22, fig. 19).

The other differences are very slight. I find, for example, a few spines on the lateral processes, and the division between the first and second segments of the trunk well marked on the ventral side. Dohrn remarks (p. 155) that the genital openings are not situated upon special projections. This is eminently true of the males, in which they differ from Ammothea, but in the females I find a slight prominence at the distal end of the second coxal joint (pl. 21, figs. 17, *ventral* and at the *distal extremity*. Hoek's figures show a similar condition (Hoek, '81, pl. 14, fig. 5). This protuberance is longer and less conical on the third and fourth legs, where it bears the opening of the genital duct. I believe that the genital ducts open only on these legs, for I was unable to make out a duct in the protuberance of the first and second legs, or an opening at the apex, both of which were plainly evident in the others. Neither do I find lateral protuberances on the femoral joint, such as Hoek describes and figures, but on the dorsal side of the joint is a long, narrow opening with a raised, thin, chitinous edge, and with several transverse partitions crossing it (pl. 22, figs. 27, 24). This is probably the external opening of the so called 'femoral gland,'— a gland which occurs in the fourth joint of the leg of the males in at least a considerable number of species of pycnogonids (Hoek, '81, p. 106). Hoek mentions finding this gland in *A. insignis*, but says it opens by "only a single pore at the end of the joint, placed at the tip of a conical excrescence."

Comparative dimensions.

	A. insignis.	*A. insignis bermudensis.*
Length of proboscis,	2 mm.	1.5.mm.
Total length of body,	6 "	4.8 "
Length of abdomen,	0.5 "	0.7 "
Length of oviger,	4.2 "	3.4 "
Length of leg of 1st pair,	19 "	13 "
Extent,		25 "

It will be seen by a glance at the figures above that *A. insignis bermudensis* averages nearly a third smaller than *A. insignis insignis.*

The most striking character of the Bermuda subspecies is its color, which affords a good example of protective coloration. This consists of alternate bands of red and yellow on the legs, the yellow usually occupying the proximal end of the joint. The trunk is more uniformly red. Figure 1 (pl. 20) shows the general appearance of the animal in the living condition enlarged four and one half times,[1] while figure 2 represents under the same enlargement a small branch of *Obelia marginata* Allman, in which it will be observed that the general color plan is very similar to that of the pycnogonid. This protective resemblance is heightened by the slenderness of the legs and body, which are of nearly the same diameter as the branches of the hydroids. The combination of form and color in this subspecies makes the animals very inconspicuous, and in order to find them it is necessary to look the hydroids over piece by piece with great care. Some idea of the protection thus afforded is given in figure 3 (pl. 20) where a pycnogonid is shown clinging to the hydroids, both being drawn natural size.

---

[1] This figure and figure 2 are redrawn from color sketches from the living animals kindly made for me by Mr. H. B. Bigelow.

One male was found carrying eggs. These were in nearly a dozen small, irregularly rounded masses. The eggs themselves are very small, so that there are large numbers of them in a single mass.

As is shown in the table below, only four specimens were found, all males, and all came from the 'cut' connecting Harrington Sound with Flatts Inlet. The single specimen of *A. insignis* taken by the 'Challenger' was dredged at Bahia (Brazil) in 7 to 20 fathoms of water.

Specimens examined.

Locality.	No. of specimens.	Date.	Source.
Flatts Inlet . . . . (B. B. S. sta., 1403)	1 ♂	17 July, 1903	(Coll. by L. J. C.)
Flatts Inlet . . . . (B. B. S. sta., 1403)	1 ♂ (w. eggs)	18 July, 1903	(Coll. by L. J. C.)
Flatts Inlet . . . . (B. B. S. sta., 1403)	2 ♂	28 July, 1903	(Coll. by L. J. C.)

EXPLANATION OF PLATES.

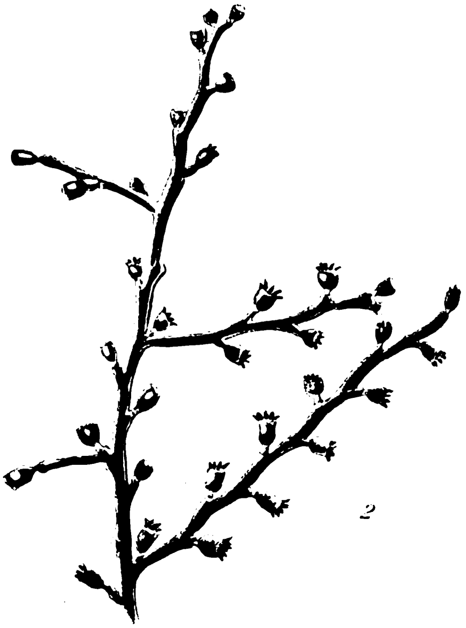
PLATE 20.

Anoplodactylus insignis bermudensis, subsp. nov.

Fig. 1. Adult male viewed from above, showing colors of the living animal. × 4.5.

Fig. 2. Portion of small branch of hydroid, *Obelia marginata* Allman, in colonies of which the pycnogonids are found. × 4.5.

Fig. 3. A specimen of Anoplodactylus among the hydroids, showing how inconspicuous it is, both on account of its slender form and its coloration. Natural size.



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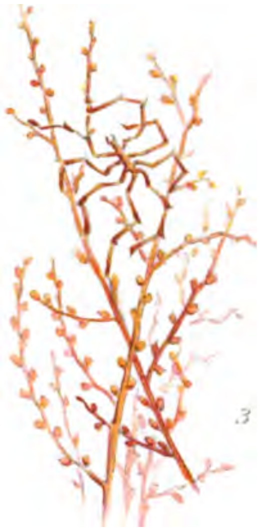

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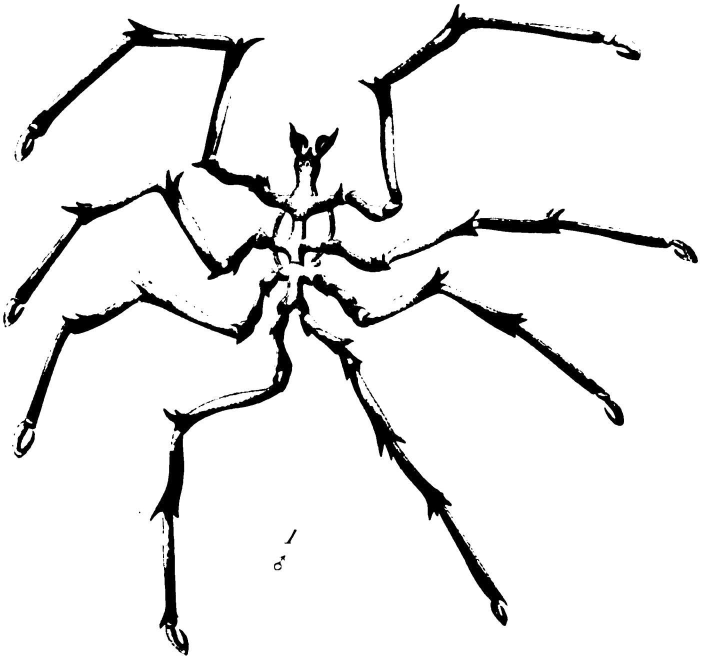

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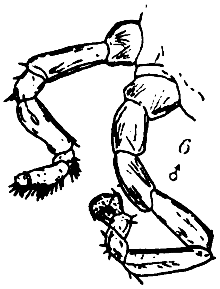
PLATE 21.

Fig. 4–14. *Ammothea gracilis* (Verrill).

Fig. 4. Female viewed from above. × 22.
Fig. 5. Female, from right side. Appendages of right side removed. × 38.
Fig. 6. Left palp and oviger of male. × 56.
Fig. 7. Left palp and oviger of female. × 56.
Fig. 8. Chelifori of adult female, from above. Same specimen as fig. 4. × 112.
Fig. 9. Foot of female. Same specimen as fig. 4. × 56.
Fig. 10. Terminal part of oviger of male. × 253.
Fig. 11. Coxal joints of fourth left leg of male, anterior aspect, showing the short genital projection on the ventral side at the distal end of the joint. × 56.
Fig. 12. Right cheliforus of an immature specimen, seen from above. × 112.
Fig. 13. Profile of eye tubercle, seen in posterior view. × 112.
Fig. 14. Coxal and femoral joints of second right leg of male, posterior aspect, showing the spinose projections on the first and second coxal joints and the absence of a genital projection on the second. × 22.

Fig. 15–18. *Ammothella appendiculata* (Dohrn).

Fig. 15. Adult male from left side. Legs of left side removed. × 38.
Fig. 16. Right cheliforus of immature specimen, from above. (Yale univ. museum, no. 3362.) × 112.
Fig. 17. Leg of female, second pair. × 24.
Fig. 18. Ventro-distal portion of second coxal joint of fig. 17, enlarged to show the prominence upon which the opening of the genital duct is situated. × 94.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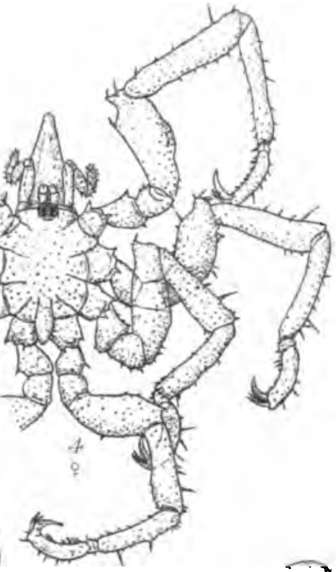
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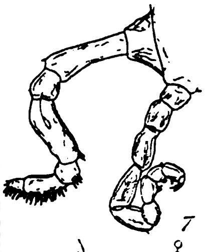
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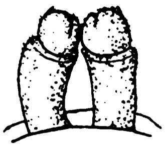
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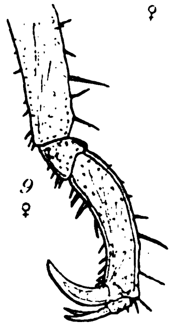
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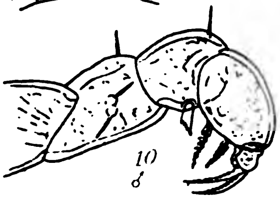
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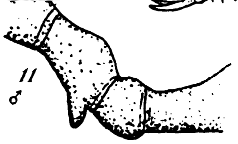
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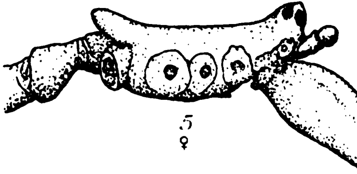
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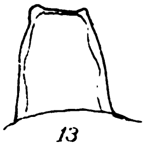
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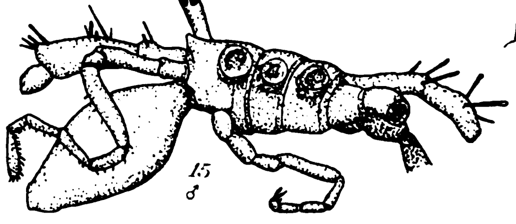
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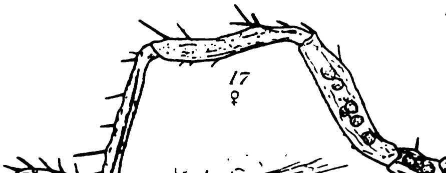
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PLATE 22.

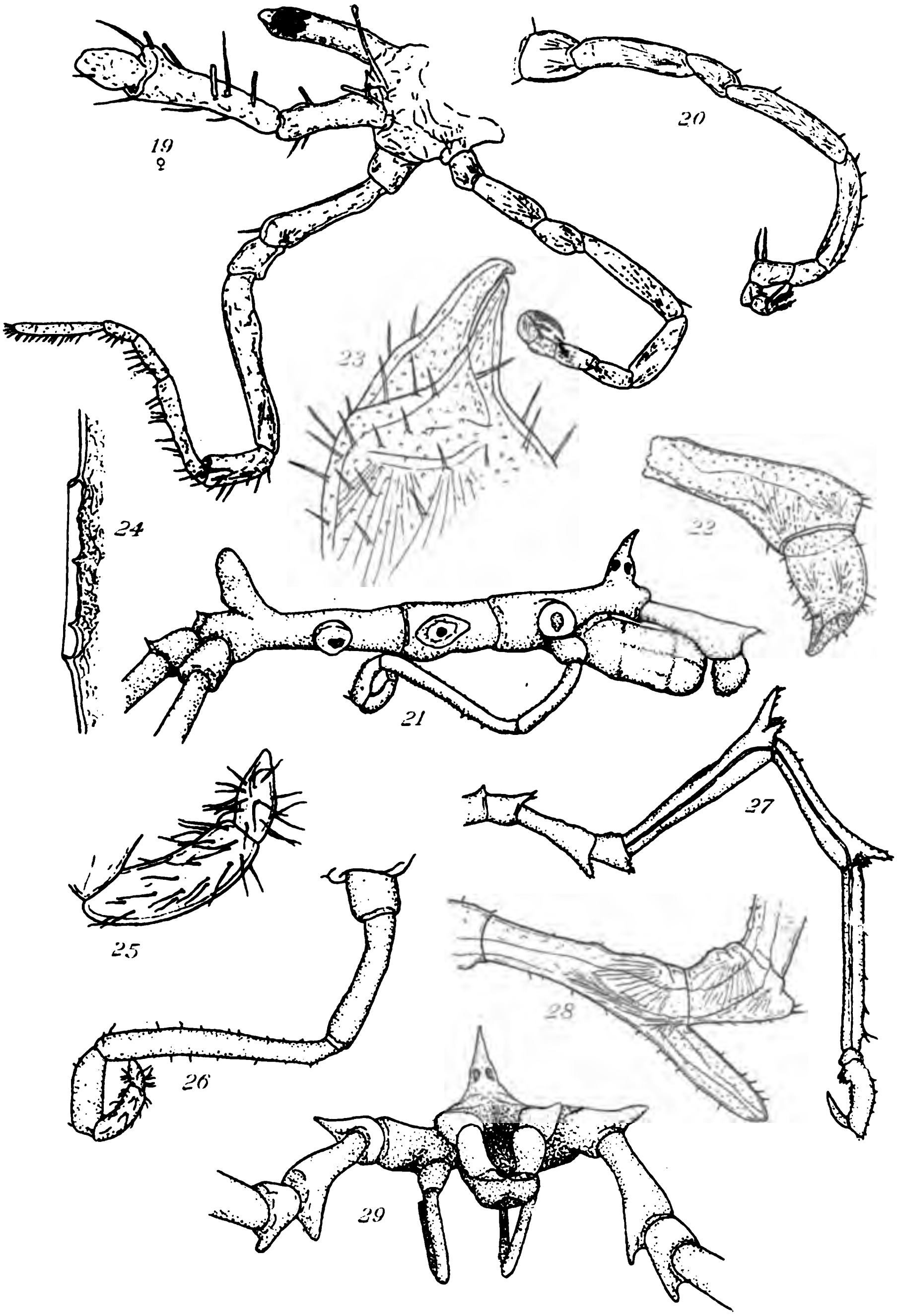
All figures except 19 are of the *male*.

Figs. 19, 20. *Ammothella appendiculata* (Dohrn).

Fig. 19. Eye tubercle and left cheliforus, palp, and oviger of female. × 65.
Fig. 20. Oviger of male. × 65.

Fig. 21–29. *Anoplodactylus insignis bermudensis*, subsp. nov.

Fig. 21. Adult male, from right side. Legs of right side removed. × 15.
Fig. 22. Left cheliforus of same specimen, seen from median side. × 28.
Fig. 23. Chelae of same, more highly magnified. × 94.
Fig. 24. Opening of gland on dorsal side of femoral joint of male. × 56. Compare fig. 27.
Fig. 25. Terminal joints of oviger. × 62.
Fig. 26. Left oviger, median face, from specimen shown in fig. 21. × 22.
Fig. 27. Second right leg of male, posterior aspect. × 9.4
Fig. 28. Coxal joints of third right leg of male, posterior aspect, showing the long projection on the second joint, which bears the opening of the genital duct. × 22.
Fig. 29. Adult male, viewed from in front, to show the position assumed by the chelifori, their relation to the proboscis, and the shape of the eye tubercle in antero-posterior view. × 15.



L. J. C. del. B. Meisel lith. Boston

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CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL LABORATORY
FOR RESEARCH.

No. 2.

THE FOSSIL LAND SHELLS OF BERMUDA.

By Addison Gulick.

With Three Maps and One Plate

From the Proceedings of The Academy of Natural Sciences
of Philadelphia, April [June 25], 1904.

CAMBRIDGE, MASS., U. S. A.
July, 1904.

THE FOSSIL LAND SHELLS OF BERMUDA.[1]

BY ADDISON GULICK.

Last summer (1903), through advantages offered by the new Biological Station in Bermuda, I was able to collect the shells on which this paper is based. In the study of the material I owe much to Dr. H. A. Pilsbry, of the Academy of Natural Sciences of Philadelphia.

It will be necessary in the discussion of the fossils to compare them with the species that are now native, in the looser sense, to the islands. In drawing the line between these and the snails supposed to have been brought by commerce, I shall follow Dr. Pilsbry's latest paper on the "Air-breathing Mollusks of the Bermudas."[2] I shall also rule out all the littoral species, including *Truncatella*, because the fossil beds were not situated where such shells could be expected.

The most unsatisfactory feature of work on Bermudian fossil land shells is the difficulty in determining the ages of the various deposits. The rock of Bermuda is exclusively solidified dunes of calcareous sand, and the soil is the rust-colored residue of the weathered rock. In weathering, the surface of the rock becomes completely broken up into pockets and crevices packed with the earth. It is estimated[3] that every inch of earth must represent eight or nine feet of rock eroded, and thus when it is possible to judge of the average depth of soil formed over a deposit, that depth can be made an index of the age of the deposit.

Probably the oldest good fossiliferous deposit that I examined is collecting locality No. 807 (see Map No. 3) of the Bermuda Biological Station, at a hard-stone quarry on the west side of Knapton Hill, about midway between Hotel Frascati and "Devil's Hole." At this point a layer of eight or ten inches of red earth containing shells was covered by an ancient dune. The dune has become hard limestone, and its top has been eroded until now the red earth in its pockets must represent a layer averaging not less than six inches in thickness. The series of *Pœcilozonites* that we took from this bed is very incomplete, and the fossils of all the genera are poorly preserved, but notwithstanding this we are able to recognize at least eleven species and subspecies. These are enough to identify its fauna with that of another deposit, locality No. 806 (see Map No. 2), where the shells are abundant and well preserved, but with no external evidence by which to estimate their age. This locality is another hard-stone quarry, where the excavations have uncovered a number of crevices and a cavern of considerable size. The shells are in stalagmitic conglomerate at the mouth of the cavern, and in the crevices, and also in the earth that fills certain of the pockets. They may represent a considerable period of time, but there is no way to distinguish any difference in age.

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[1] Contributions from the Bermuda Biological Station for Research, No. 2.

[2] *Trans. Conn. Acad.*, Vol. X.

[3] A. E. Verrill, *Trans. Conn. Acad.*, Vol. XI, p. 490.

Another deposit at the same locality as the one last mentioned is a horizontal band of slightly reddish rock about half-way up the face of the quarry, and from two to three inches thick. This is part of the rock out of which the cave and pockets were eroded, so that the shells here are very much older than the others at No. 806; but here, again, there is no basis for a comparison with the date of No. 807. The remains here are obscure casts of *Pœcilozonites circumfirmatus* and of what appear to be *Vertigo* and *Carychium.*

I collected from three other beds in this neighborhood what seem to represent the same formation as the pockets of No. 806.

The first of these, locality No. 814, is a newly opened quarry just south from Coney Island. A red-earth pocket here contained a fine series of *Pœcilozonites nelsoni*, very large, but wanting the most extreme examples of both the elevated and the depressed variations. There are also fossiliferous conglomerates in caverns at this quarry, but they are composed of gravel too fine to contain *Pœcilozonites nelsoni.*

The best fossil specimens of *Pœcilozonites reinianus* came from locality No. 815, near Harrington House. They are noticeably larger than the recent specimens. No. 816, near 815, but on the shore of Castle Harbor, has large numbers of *Pœcilozonites bermudensis zonatus* and *Pœcilozonites reinianus*, the former associated with *Pœcilozonites nelsoni* in a conglomerate.

Bifidaria rupicola, found in the red earth of No. 806, may perhaps be an importation subsequent to the formation of No. 807, and *Strobilops hubbardi*, found at the same place, possibly may not have been a permanent resident; but we can safely assume that all the other species from the above localities belong to the epoch of the red-earth streak at No. 807. The remaining three deposits from which I collected are clearly much more recent than No. 807. These are in sand pits, in the nearly pure sand of partially solidified dunes. None of them have any clear signs of red earth, either about them or overlying them.

The shells at these places are so perfectly preserved that even the term "semi-fossil" seems a misnomer for them. Probably the sand preserves them by saturating the water with lime before it reaches them.

One of these shell deposits, locality No. 818, on the land of Mr. Benjamin Trott, in Tucker's Town, is only from 8 to 36 inches below the surface. The *P. nelsoni* were mostly in the upper foot of the deposit, where the bank is thoroughly solidified by the rain; but a few inches lower the sand is still loose enough to be scraped out with a strong hoe.

The two localities last to be mentioned, Nos. 808 and 809, are essentially alike. They face the Devonshire marshes on the northwest side—808 near the north end and 809 close to the barracks. The sand in these dunes appears to have drifted from near the present line of the north shore—a consideration which may yet give a clue to their age.

The following are my records of fossil and semi-fossil shells in these localities:

Locality 807.

PŒCILOZONITES NELSONI.
" NELSONI CALLOSUS.
" CIRCUMFIRMATUS, } Intergraded.
" DISCREPANS. }
EUCONULUS TURBINATUS.
ZONITOIDES MINUSCULUS.
" BRISTOLI. One specimen.
THYSANOPHORA HYPOLEPTA.
SUCCINEA BERMUDENSIS.
VERTIGO NUMELLATA.
" MARKI?
CARYCHIUM BERMUDENSE.

Casts in the Rock, Locality 806.

PŒCILOZONITES CIRCUMFIRMATUS.
VERTIGO.
CARYCHIUM?

Cave and Pockets, Locality 806.

PŒCILOZONITES NELSONI. Both extremes in height of spire.
" BERMUDENSIS ZONATUS.
" REINIANUS.
" CIRCUMFIRMATUS.

Pœcilozonites cupula.
Euconulus turbinatus.
Thysanophora hypolepta.
Succinea bermudensis.
Strobilops hubbardi.
Bifidaria rupicola. One specimen.
Vertigo numellata.
" marki.
Carychium bermudense.

Locality 814.

Pœcilozonites nelsoni,
" reinianus. In one pocket.
" nelsoni. In crevices
" bermudensis zonatus,
" reinianus,
" circumfirmatus,
Euconulus turbinatus. In stalagmitic conglomerate.

Locality 815.

Pœcilozonites bermudensis zonatus? Small fragments only.
reinianus.

Locality 816.

Pœcilozonites nelsoni.
" bermudensis zonatus.
" reinianus. (None kept in the collection.)
Euconulus turbinatus.

Locality 818 (Sand Pit).

Pœcilozonites nelsoni callosus.
" reinianus.
" discrepans.
Euconulus turbinatus.
Zonitoides bristoli.
Succinea bermudensis.
Bifidaria servilis. One specimen.
Carychium bermudense.

Locality 808 (Sand Pit)

Pœcilozonites bermudensis zonatus.
" reinianus.

Pœcilozonites circumfirmatus.
Euconulus turbinatus.
Succinea bermudensis.
Bifidaria rupicola. One specimen.
Carychium bermudense.
(Polygyra microdonta? One immature specimen, which may have crawled into the sand in recent times. We shall give it no further notice.)

Locality 809 (*Sand Pit*).

Pœcilozonites bermudensis zonatus.
" reinianus.
" circumfirmatus. (None kept in collection.)
Succinea bermudensis. (None kept in collection.)
Carychium bermudense.
Pupoides marginatus. One specimen.

These lists include all the known fossils except *Pœcilozonites dalli.*

Outside of *Pœcilozonites*, the species that do not appear in deposit No. 807 are:

Strobilops hubbardi.
Bifidaria rupicola.
" servilis.
Pupoides marginatus.

The last two of these appear only in the sand pits, and are in all probability later importations. The first two, found at No. 806, may also have arrived after No. 807 was covered up, but the fossils at No. 807 are so poorly preserved that we cannot presume upon the absence of these species. Ignoring these doubts, we may combine and rearrange the lists from Nos. 807 and 806—the more ancient fossils—mentioning after each species the habitat of its nearest relatives in other countries, as follows:

Pœcilozonites nelsoni.
" nelsoni callosus.
" cupula.
" bermudensis zonatus.
" reinianus.
" circumfirmatus.
" discrepans.

Euconulus turbinatus.	Eastern North America.
Zonitoides bristoli.	
Vertigo numellata.	
" marki.	
Carychium bermudense.	
[4]Zonitoides minusculus.	North America and West Indies.
[4]Bifidaria rupicola.	Florida, Cuba.
[4]Strobilops hubbardi.	Florida, Jamaica.
Thysanophora hypolepta.	West Indies.
Succinea bermudensis.	West Indies.

Total, 17 forms, 14 of them probably peculiar to Bermuda. For comparison we have the following *recent* species, supposedly not imported by man:

Pœcilozonites bermudensis	Remnant of the fossil fauna. Seven species.
" reinianus,	
" circumfirmatus,	
[5]Zonitoides minusculus,	
Thysanophora hypolepta	
Succinea bermudensis,	
[5]Bifidaria rupicola.	
[5]Pupoides marginatus.	North America, West Indies.
[5]Thysanophora vortex,	West Indies. Five species.
[5]Polygyra microdonta,	
[5]Bifidaria servilis,	
[5]Bifidaria jamaicensis,	
Helicina convexa.	

Total, 13 species, 6 of them probably peculiar to Bermuda.

Dr. Pilsbry's conclusion, from the anatomy of *Pœcilozonites*, that the oldest importations to Bermuda came from continental America, is thus confirmed by a large majority of the fossil forms. Bermuda, at the time of the No. 807 deposit, was characterized by not less than five genera of continental affinities, of which at least one had been resident long enough to have developed new generic characters and a respectable diversity of species. The abundance of the individuals, too, and the size and variability of some of the species, seem to show that the island was not inhospitable to continental genera at that epoch. There were not only the large extinct species *Pœcilozonites nelsoni* and *Pœcilozonites cupula*, but larger varieties also of *Pœcilozonites bermudensis* and

---

[4] Species not peculiar to Bermuda.

[5] Species not peculiar to Bermuda.

Pœcilozonites reinianus than are now living. The largest specimens even of *Pœcilozonites circumfirmatus* and *Succinea bermudensis* are among the fossils. These snails must have found more food than there is now on the uncultivated ground. There is also geologic evidence that they belonged to a more prosperous epoch than the present. Prof. Heilprin reports that in excavations for one of the docks, specimens of *Pœcilozonites nelsoni* were brought up from a peat deposit at a depth of forty feet below water. A rise of the land sufficient to put these shells ten feet above sea-level (see Map No. 1) would multiply the land area eight or ten times, changing it from a narrow ridge, hardly two miles wide at its widest, into an elliptical area, including, it is true, some large lagoons, but in all about ten miles across and more than twenty miles long. A large, protected interior valley would then receive the fertile soil that is now washed into the lagoon by every storm. It would not surprise me if the deposits at locality 807 should be shown to date from the period of this Greater Bermuda, but a person need hardly wait for this proof before supposing that the indigenous contemporaries of *Pœcilozonites nelsoni* were also characteristic of Greater Bermuda.

In spite of their evident prosperity, I do not think it could be proved that these snails lived under any densely shading vegetation. The humidity at Bermuda makes such a shade less necessary for snails than it is in many places. I have often seen *Succinea bermudensis* clinging to grass and to trunks of trees in such situations that I imagine an American summer day would have desiccated them. The tract about Prospect Hill (No. 809) must have been desolate, unshaded land when the hills were growing dunes, yet the sand here (localities 808 and 809) contains numerous well-developed specimens and quite a variety of species. These must either have lived where they are found, or else have been blown there from some place almost equally wind-swept.

The extinction of species that were able to prosper on those barren parts of the island seems to me a strange occurrence. If, as I believe is probable, the sand for these dunes came from near the present north shore, then the island must have had very nearly its present shape and size when these snails were alive. Thus when the Greater Bermuda sank, the change seems to have set new dunes in motion across this section of the Lesser Bermuda; and *Pœcilozonites zonatus*, *Carychium bermudense* and *Euconulus turbinatus* not merely survived the subsidence, but even formed a considerable population on the parts of the remaining island that were most damaged by the changing conditions. How many other species still survived in the less altered sections it is impossible to say. It is hardly possible to prove that even the set of fossils from No. 806 belong to any earlier date. Indeed we might draw an analogy between *Bifidaria rupicola* at No. 806, which may be one of the later arrivals, and *Bifidaria servilis* at No. 818 and *Pupoides marginatus* at No. 809, either of which we can hardly hesitate to treat as recent arrivals. But however this may be, the sand-pit deposits are against the supposition that the *Carychium* and its hardier associates were exterminated merely by the increasing barrenness of the island. We should be in a better position to discuss the other causes if we knew whether these species survived till after the West Indian arrivals had begun to take possession of the land. The West Indies snails, especially *Polygyra microdonta*, of Bahama, are at present much the commonest of the "native" snails, and it may be that their special fitness for the more barren land of the new Bermuda made them deadly competitors to the old species. The newer formations at the west end of the islands, which I had not the time to visit, may perhaps be the ones in which to look for evidence on this question.

NOTES AND DESCRIPTIONS.

Thysanophora vortex Pfr.

Living animals quite abundant under stones; but I looked in vain for fossil specimens. Greater Antilles, Bahamas, Southern Florida.

Thysanophora hypolepta 'Shuttl.' Pils.

I found more examples of this than of *Z. minusculus* among the fossils, but among the living snails *Z. minusculus* seems to be far more abundant. It is supposed to be indigenous.

Polygyra microdonta Desh.

Excluding importations from Europe, this species is the one now most in evidence. It is partial to the coarse native grass, but is to be found almost everywhere. I was surprised not to find any indubitable specimens of this in the sand pits. I hope other collectors will look for it. Bahamas.

Strobilops hubbardi Brown.

An adult and an immature specimen from locality 806. The adult is somewhat larger than the usual size on the continent. Alt. 1.2. diam. 2.8 mm. Habitat, the Gulf States and Jamaica.

Vertigo numellata n. sp. Pl. XXXVI, fig. 6.

Shell rimate, minute, elliptical or bluntly pupiform, yellowish-corneous, faintly striate, of 5 rather convex whorls; the diameter through the body whorl not much greater than that through the whorl preceding. A prominent, whitish, inflated ridge, appearing like a second peristome, occurs behind the peristome. Aperture proportionately more contracted than that of *V. ovata;* set with a parietal, an angular and a columellar lamella; and with two palatal and a basal fold. The palatal folds are prominent, the upper one slightly double-topped, the lower one more immersed and entering spirally. The parietal lamella is stout and blunt; the angular lamella smaller and thinner; the columellar lamella and the basal fold low and blunt. Peristome rather thin, expanded, and notched opposite the upper palatal fold, as in *V. ovata.*

Alt. 1.7, diam. .9 mm.

In one specimen there appears a slight suprapalatal denticle. A considerable number of smaller, more globose specimens seem to belong to this species. One of these from locality 806 measures 1.4 x .9 mm.

I have assumed that this species is more closely related to *V. ovata* than to any of the species reported from the West Indies.

Localities 806 and 807; the type from 806.

This is the common fossil *Vertigo.*

Vertigo marki n. sp. Pl. XXXVI, fig. 7.

Shell rimate, ovate, yellowish-corneous, faintly striatulate; whorls nearly 5, rather convex. Apex obtuse, but not rounded like that of *Vertigo numellata.* The inflated ridge inconspicuous, whitish, crowded close to the peristome. Aperture ovate, much longer than in *Vertigo numellata,* set with four denticles, of which the parietal lamella is the largest. The lower palatal fold denticular, smaller than that of *Vertigo numellata* and less immersed; the upper palatal fold minute; and the columellar lamella broad and low. The peristome is expanded, white, strongly thickened within, hardly notched at the upper palatal fold.

Alt. 1.9, diam. 1 mm.

Named in honor of Dr. E. L. Mark, of Harvard, Director of the Bermuda Biological Station for Research.

This species is somewhat suggestive of *V. tridentata,* but is a little slenderer, with a longer aperture, and a heavy white peristome.

Locality 806; doubtful specimens from 807.

Bifidaria rupicola Say.

One specimen each from localities 806 and 808, and several recent specimens. Dr. Pilsbry reminds us that the Bermudian form has a thicker lip than the others of this species. Cuba, Florida.

Bifidaria servilis Gld.

One specimen from locality 818, and a few recent. Cuba and other West Indian islands.

Bifidaria jamaicensis C. B. Ad.

The commonest of the recent Pupidæ, but I failed to find it fossil. Greater Antilles.

Pupoides marginatus Say.

I got one indubitable specimen from locality 809, but it went to pieces in my hands. I found only two or three recent ones. Mr. Owen Bryant, who was collecting at the same time, found a larger number. Eastern and Central North America, and some West Indian islands.

Carychium bermudense n. sp. Pl. XXXVI, figs. 11, 12.

Shell almost regularly tapering, corneous-white, imperforate, finely striate; whorls about 5, increasing regularly, those of the spire very convex, with deep sutures. Aperture quite oblique, obstructed by a small parietal and a very minute, deeply placed columellar lamella. Peristome broadly expanded and reflexed, thickened within by a white callus, with a slight groove on its front face, and developed inward to form a prominence slightly above the middle of the outer margin (near the position of the upper palatal fold in *Bifidaria*).

Alt. 1.8, diam. .9 mm.

This species is very dissimilar to the slender *Carychium jamaicense.* The shape of the aperture allies it more nearly to *Carychium exiguum* of North America, but its heavy peristome is quite its own.

It is one of the most abundant fossil species, occurring in the red earth of localities 806 and 807, and even in the sand that fills the larger shells in the sand pits.

Pœcilozonites nelsoni (Bld.).

Hyalina nelsoni Bld., Ann. Lyc. N. H. of N. Y., XI, 1875, p. 78.
P. nelsoni Pilsbry, Proc. Acad. Nat. Sci. Phila., 1888, p. 290.
P. nelsoni v. Mart., Sitzungsber. Ges. Nat. Freunde, Berlin, 1889, p. 201.

The typical form of this species is, I suppose, the large, moderately elevated form. This is represented among my specimens from locality 814, where the variation in dimensions is as follows:

Alt.	Diam.
29	39 mm.
28	37
27	41
27	40
26	35
25	39
23.5	36
23	41.5
23 (estimated)	35

The way these lay, piled together in a little pocket, compels the supposition that they lived at about the same time, and their variations in outline show what may occur in a single intergenerant colony. The specimens from locality 806 show even greater differences, of which the following are the extremes:

Alt. 34	Diam. 34 mm.
31	33
19	37
19.5	39

I should like to suggest the name *discoides*, merely as a convenient term by which to know the variation represented by the last two shells (Pl. XXXVI, fig. 4). I must say, however, that this suggestion would be unfortunate if it resulted in the division of the series obtained from locality 814. It seems to me, rather, that some physiological peculiarity has destroyed the diagnostic value of the elevation of the spire. The upper whorls differ less than the lower, and in the most elevated forms the suture of the later whorls is much below the keel of the preceding whorl, as if the slant of the spiral had been abnormally diverted downward.

Pœcilozonites nelsoni var. callosus n. var. Pl. XXXVI, fig. 5.

Shell smaller than the typical form, shiny, with heavy ribbed striæ, colored with a broad yellowish-brown peripheral band on a white ground. Whorls a trifle more than nine, increasing regularly and very gradually. The suture does not change its character nor become deflected from the peripheral line of the preceding whorl. The usual peripheral angle is almost obsolete. The base has a stronger angle about the umbilical perforation than is usual in the species. The peristome is greatly thickened on the inside from 1 mm. at the suture to fully 2 mm. near the columella. A prominent callosity covers the parietal wall of the aperture.

Alt. 24, diam. 33 mm.

The combination of small size and large number of whorls is characteristic. The ratio of height to diameter is more constant than in the typical form, and the tendency to produce the callosity is very marked.

Type from locality 818, others from 818 and 807.

The stability of the variety, occurring as it does in the oldest and the latest formations, is the most interesting thing about it. It is also my excuse for regarding such slight distinctions in a remarkably variable species.

I suppose the color patterns of *Pœcilozonites nelsoni* were essentially the same as those on the living *Pœcilozonites bermudensis*. For example, the type specimen of *callosus* probably had a dark brown band on a background of a yellowish cuticular color. The depressed specimen which is figured has traces of a subperipheral band, a supraperipheral line, and radial flaming above this line. This flamed pattern appears in several of the flat specimens.

Pœcilozonites cupula n. sp. Pl. XXXVI, fig. 2.

Shell solid, dome-shaped, with somewhat flattened base, perforate, strongly striate; pale, shiny-corneous, with subsutural and subperipheral bands of darker color, and faint traces of two narrow bands on the periphery. Whorls 7⅔, a little convex, increasing slowly; the last vaguely angulate at the periphery. The aperture is somewhat quadrangular on account of the straight, vertical columella and the peripheral angle. The peristome is simple, thin, with the columellar margin reflexed.

Alt. 13 Diam. 16 mm.

Locality No. 806.

Other specimens measure:

Alt.	Diam.
13.5	16.5 mm.
12.5	17
13	19
13	20
15	15.5

The last specimen has 8¾ whorls.

The type was selected as the best-preserved specimen, not as the most representative example. The majority of the specimens have a more rounded base and periphery, giving the peristome a more oval contour. The height of the shell and the absence of a keel distinguish it readily from *P. bermudensis zonatus*, and the very round dome and less angulate periphery separate it from immature specimens of *nelsoni*.

Pœcilozonites dalli n. sp. Pl. XXXVI, fig. 1.

Shell elevated, with rounded apex and convex base, perforate. Its surface is polished, with incremental lines less pronounced than those of *P. cupula;* milky-white, with a yellowish-brown band below the periphery and a line above the periphery. The first four whorls are translucent whitish. Whorls 7⅛; all but the final whorl are flat as if keeled, that one has a blunt peripheral ridge, below which it is deeply rounded. The aperture is quite oblique, round-lunate. The peristome is simple, except at the columella, which it joins without an angle, but the columellar margin is reflexed, partly covering the perforation.

Alt. 8.5 Diam. 7.3 mm.

Another specimen has the height 10, diam. 7 mm., and is composed of 9 whorls. It shows more of the brown and less of the white color.

The extreme variability of *P. cupula* leaves it debatable whether this may not be a dwarf race of that species.

No specimens of this form were found last summer, and it is through the courtesy of Dr. William H. Dall of the National Museum, that I am able to describe and figure it. The specimens came to him without labels, so that we are left to conjecture their age. The slender specimen is so glossy and brightly colored that Dr. Dall doubts whether it can be a fossil, but it seems to me the simpler hypothesis to suppose that it was preserved in the sand in the same manner as the type of *P. nelsoni callosus*, which it so closely resembles in color and polish. The shell sand seems to be a complete protection from destructive agents. On this hypothesis it had originally about the color of *Pœcilozonites bermudensis.*

Pœcilozonites bermudensis Pfr.

Pilsbry, Proc. Acad. Nat. Sci. Phila., 1888, p. 289; 1889, p. 85.

The typical variety seems to be of recent origin. It is distinguished from the fossil by a less rounded upper surface, less flattened apex, larger umbilical perforation, and usually smaller number of whorls. My largest specimen I found on Rabbit Island, Harrington Sound, buried under drift sand at some time previous to the cultivation of the island. It measures alt. 13, diam. 24.5 mm. The largest and smallest living mature shells measure as follows:

Alt. 14.5	Diam. 20. mm.
14	22
10	16.5

An average fully adult specimen measures:

Alt. 11	Diam. 20	Umb. 1.7 mm.

and has a trifle more than 7 whorls.

Pœcilozonites bermudensis var. zonatus Verr. Pl. XXXVI, fig. 3.

This differs from the type of the species in possessing an almost uniformly curved upper contour line, an almost flat apex, and a more constricted umbilicus. The keel is distinct, as in the recent form. Whorls 7¾. The aperture is surrounded by callous thickenings as in *P. nelsoni callosus*. Alt. 13.5, diam. 23, umb. 1 mm.

Specimens come from localities Nos. 806, 808, 814, 816 and 809.

The extremes from locality No. 808 are:

Alt. 16	Diam. 22.5 mm.	
15	25	
12.5	20.5	Umb. 1 mm. wide.

Thus the smallest adult is quite equal to the average recent shells. A few selected specimens of the fossil and recent shells can hardly be distinguished. Many of the fossils do not have the callosity.

Locality 816 has great quantities of these shells so firmly cemented together that most of them are worthless as specimens. They have the peculiar spheroidal upper surface, but the perforation is wider than in the series from locality 808—not so wide, however, as in the recent. Several specimens here occur below some fragments of *Pœcilozonites nelsoni* in stalagmite, apparently showing that they were there previous to the extinction of *nelsoni*.

Broken and immature specimens from locality 808 show that the umbilicus was not much narrower than that of the recent variety until the last whorl had commenced to grow. The peculiar contour is also less noticeable prior to the last whorl. Thus in their smaller number of whorls, their less rounded contour, and their larger umbilicus, the present snails seem like an undeveloped or degenerate race of the former species.

It is possible that this fossil variety is what Pfeiffer (*Monographia*, I, p. 80) mistook for *Helix ochroleuca* Fer.

Pœcilozonites reinianus Pfr.

Helix reiniana Pfeiffer, Malak. Bl., XI, 1863, p. 1.
P. reinianus Pilsbry, Proc. Acad. Nat. Sci. Phila., 1888, p. 290; 1889, p. 85.

I found this species in every deposit examined except No. 807. Further search would doubtless show it there also. At locality 815 many fine specimens were embedded in stalagmite. They show the typical color-pattern, with the dark marks changed as usual to reddish, and the lighter ground to ivory-yellow.

The largest specimen from No. 815 measured....	Alt. 7	Diam. 13 mm.
The largest from No. 808		12
The largest from No. 806		11.5
The largest from the pocket at No. 814		11
The largest recent, lent by Mr. Bryant	6	11.3
My largest recent	5	10.3

From Town Hill (locality 819) come some good specimens of var. *goodei* Pils. Examples of these measure:

Alt.	Diam.	Umb.
4	10	4 mm.
3.5	9.3	3.4
3.7	10	4

The species is not so uniformly common as *Pœcilozonites circumfirmatus*, but is very abundant in some places, for example, near locality 806. It would be interesting to learn whether its place in the economy of nature is different from that of the following species.

Pœcilozonites circumfirmatus Redf.

Helix circumfirmata Redfield, Ann. Lyc. N. H. of N. Y., VI, p. 16.
Pœcilozonites circumfirmatus Pilsbry, Proc. Acad. Nat. Sci. Phila., 1888, p. 291.

The modern variety comes from both formations at locality 806, and from 814 and 808. Those from locality 808 are some of them more keeled than is now usual. A series of poor specimens from No. 807 seem to bridge the gap from these to var. *discrepans*.

This species has lost less in size than the others of its genus. My largest fossil, coming from locality 808, has alt. 7, diam. 12 mm. My largest recent shell has alt. 7, diam. 11.5 mm. I think the fossils average larger than the adults of the recent shells, but it is not easy to eliminate the immature of either.

Pœcilozonites circumfirmatus var. discrepans Pfr.

Helix discrepans Pfr., Malak. Bl., 1864, p. 1.

Localities 807, 818 and two specimens of doubtful identity from 806. Some from 818 are extremely flat and carinate, one of them having alt. 4.8, diam. 10.5 mm. If this were the only locality that yielded the variety it would undoubtedly rank as a distinct species.

I should like to raise the question whether *Pœcilozonites discrepans* is not one of the extinct varieties. I believe it has not been treated as such heretofore, but none were found last summer any more recent than those from this sand pit.

Euconulus turbinatus n. sp. Pl. XXXVI, figs. 8, 9, 10.

Shell acutely conic, with contour very slightly convex; minutely perforate, thin, glistening yellowish-corneous, closely striate, and sculptured with microscopic spirals. Apex rounded off abruptly. Whorls 7½, not convex, narrow, the last strongly angulate at the periphery. Suture simple, hardly impressed. Base rather flat, not excavated. Aperture almost quadrangular, but with the angle at the columella indefinite. Columella slightly curved, the columellar margin narrowly reflexed. Alt. 3.4, diam. 2.8 mm. (from locality 807); diam. 3 mm. (from locality 808).

From localities Nos. 807, 806, 814, 816, 808, and 818.

The above description is a composite. The general form is described from the specimen from locality 807, but the sculpture is that of the best specimen from 806, which should, perhaps, be considered the type, and the base and aperture are taken from the specimen from 808. From 814 comes the longitudinal section of one 3.8 x 2.8 mm., with an unusually convex contour.

The genus *Euconulus* is of course, not wholly satisfactory for this species.

Zonitoides minusculus Binn.

Locality 807, and recent. Its abundance in the one deposit and absence in the others is a little surprising.

Zonitoides bristoli n. sp. Pl. XXXVI, fig. 13.

Shell resembling *Zonitoides minusculus* in general form, but much smaller, only moderately umbilicate, white, costulate, and densely sculptured with spiral lines; composed of 3 convex whorls. Apex somewhat elevated. Aperture lunate, the outer and basal margin more uniformly curved than in *Zonitoides minusculus*, and the preceding whorl cutting out a greater arc. Peristome simple, thin. Costulæ regularly spaced, coinciding with growth lines. The spaces between them crowded with fine striæ. A close, regular, spiral sculpturing crosses these lines and gives the costulæ a slightly tubercular appearance.

Alt. .7 Diam. 1.17 mm.

Named in honor of Dr. C. L. Bristol, of New York University, Associate Director of the Bermuda Biological Station for Research.

One specimen from each of localities 807 and 818; the type from the latter place.

Succinea bermudensis Pfr.

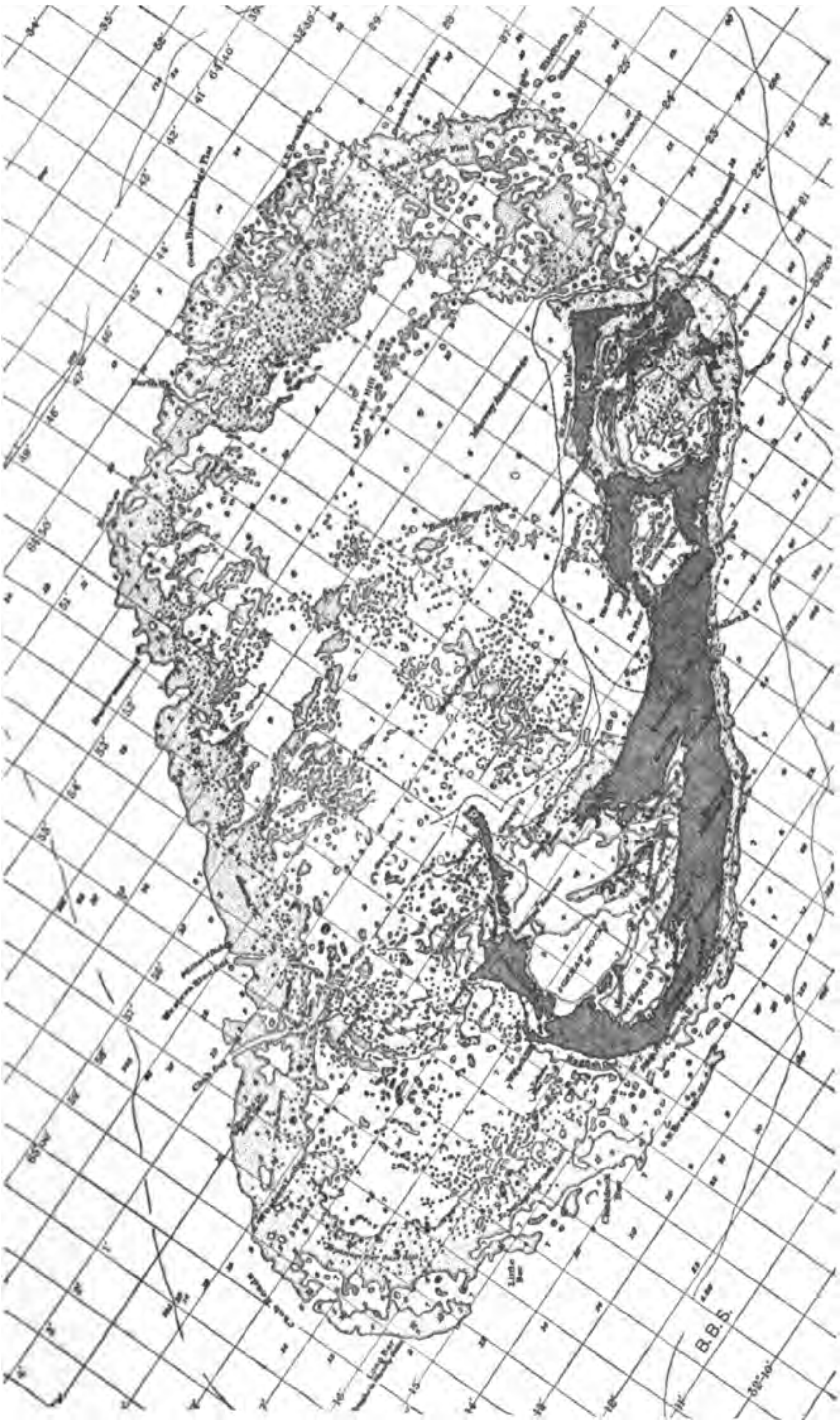
S. bermudensis Pfr., P. Z. S., 1857, p. 110; Monographia, IV, p. 817.
S. barbadensis Pilsbry, Trans. Conn. Acad., X, p. 502.

Localities 807, 806, 818, 808, 809 and recent. In the absence of alcoholic specimens of *S. barbadensis* I have given up that name and returned provisionally to the name *bermudensis*. Its presence as a fossil makes it not unlikely that it may be proved distinct from *S. barbadensis*. This is another species that was formerly larger than now. The largest fossil, from locality 808, measures alt. 13, diam. 7 mm. The largest out of 30 recent specimens lent by Mr. Bryant has alt. 12, diam. 6.3 mm.

Helicina convexa Pfr.

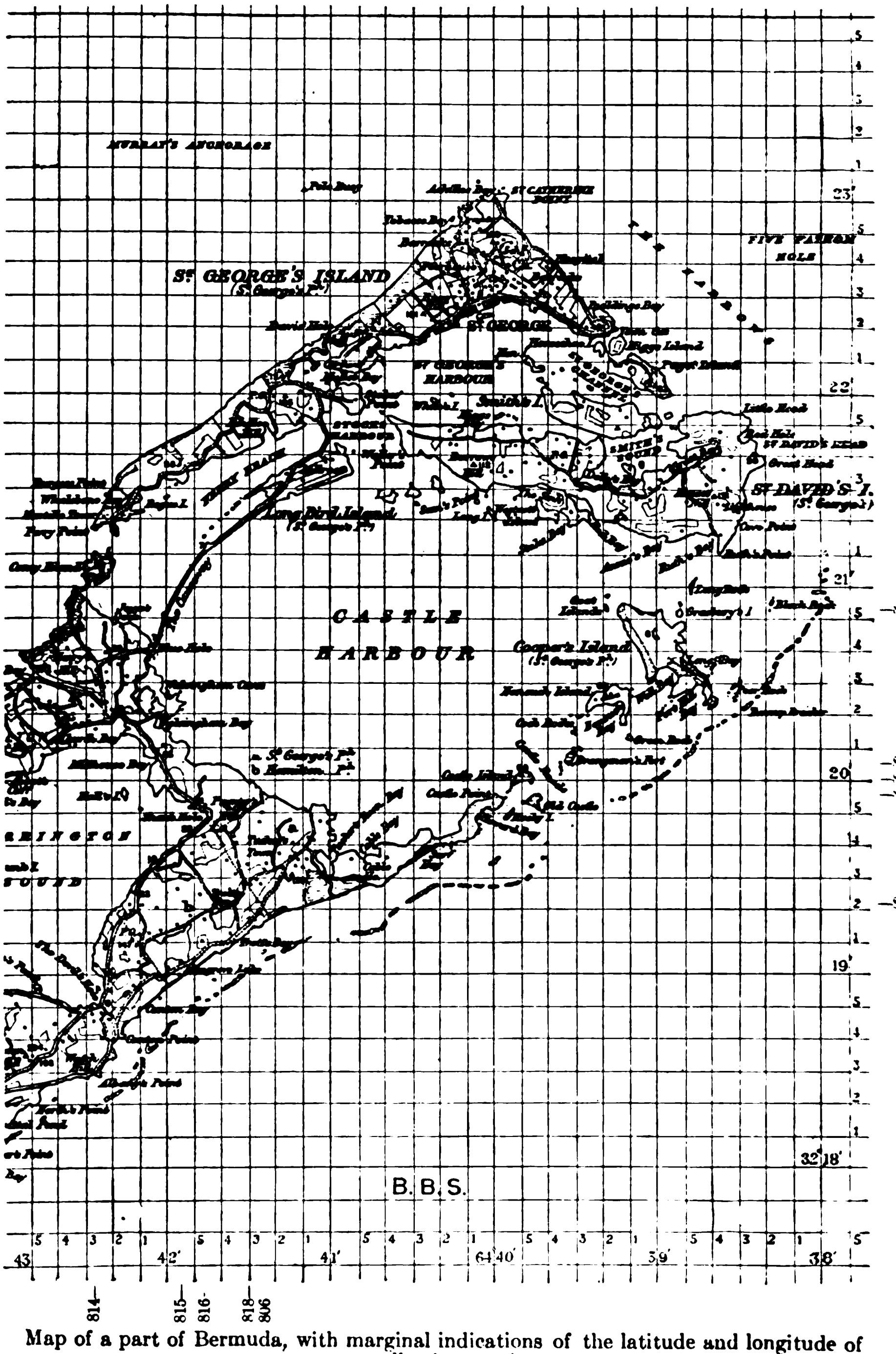
If this species were indigenous we could expect it to be as abundant formerly as it is now. Instead of that it seems to be entirely absent from the beds I examined. The evidence seems to me strong that its real home is elsewhere.

Map 1.



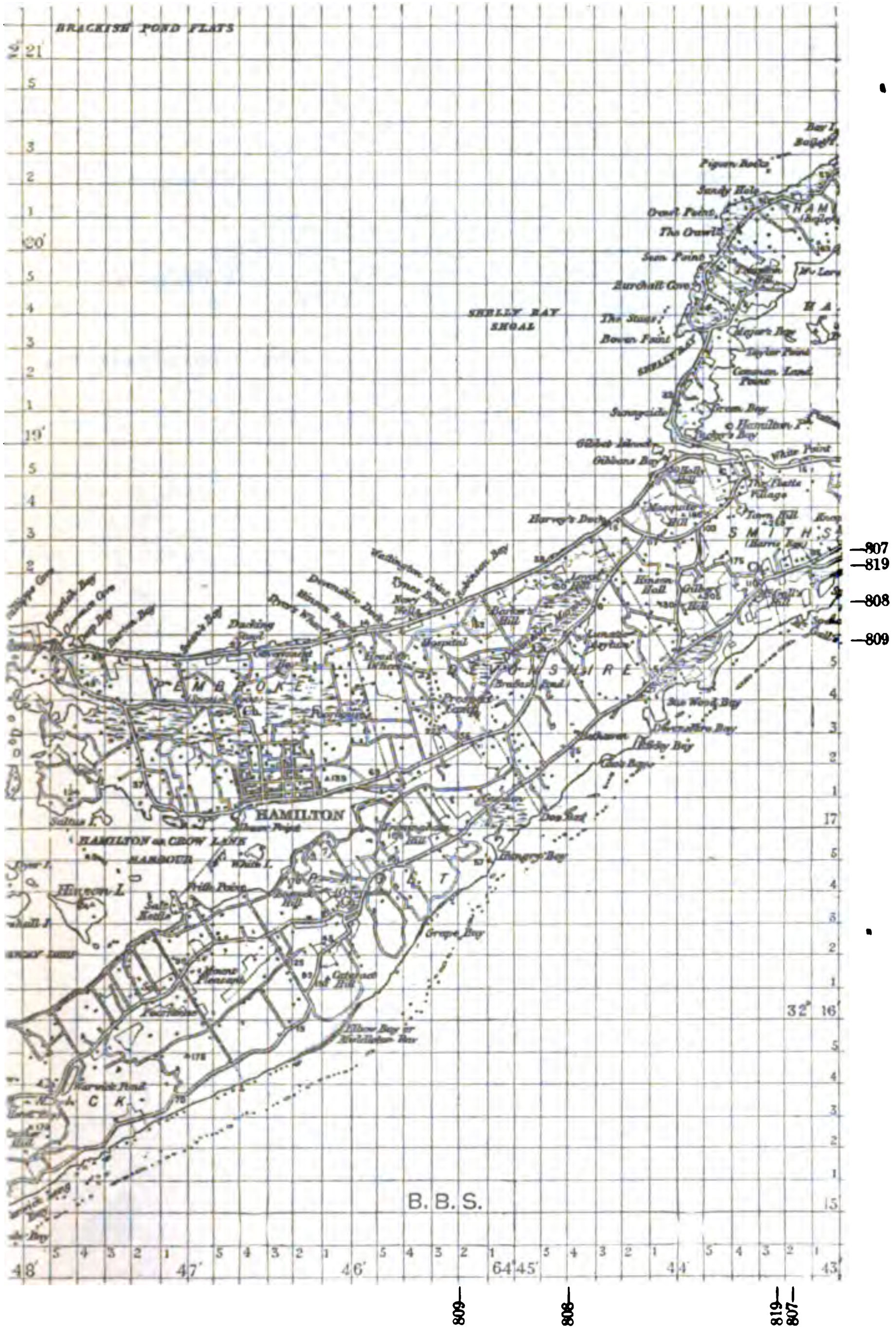
Bermuda Island.

Map 2.



Map of a part of Bermuda, with marginal indications of the latitude and longitude of collecting stations.

Map 3.

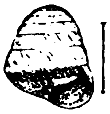


Map of a part of Bermuda, with marginal indications of the latitude and longitude of collecting stations.

Reference to Plate XXXVI.

Figures 2 to 5 are natural size; the others are variously enlarged.

Plate XXXVI Fig. 1.—*Pœcilozonites dalli.*
Fig. 2.—*Pœcilozonites cupula.* Locality 806.
Fig. 3.—*Pœcilozonites bermudensis zonatus.* Locality 808.
Fig. 4.—*Pœcilozonites nelsoni* form *discoides.* Locality 806.
Fig. 5.—*Pœcilozonites nelsoni callosus.* Locality 818.
Fig. 6.—*Vertigo numellata.* Locality 806.
Fig. 7.—*Vertigo marki.* Locality 806.
Fig. 8.—*Euconulus turbinatus.* Section from compact rock, locality 814.
Fig. 9.—*Euconulus turbinatus.* Locality 806.
Fig. 10.—*Euconulus turbinatus.* Locality 808.
Figs. 11, 12.—*Carychium bermudense.* Locality 806.
Fig. 13.—*Zonitoides bristoli.* Locality 818.



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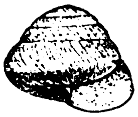

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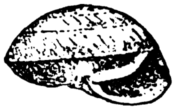

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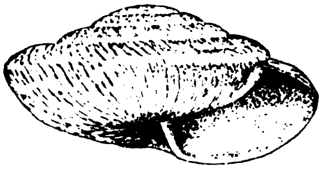

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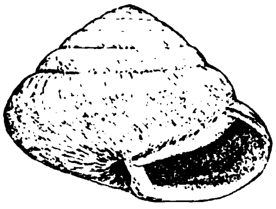

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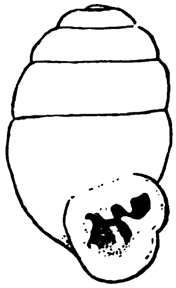

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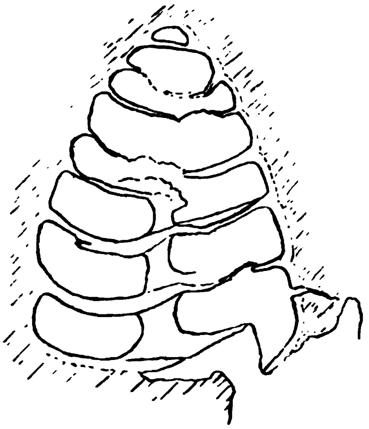

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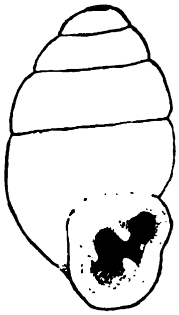

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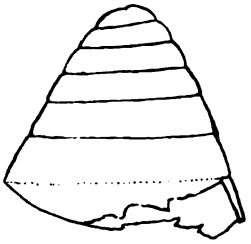

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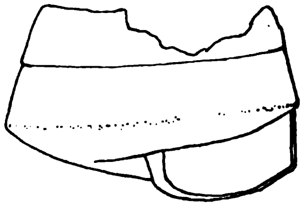

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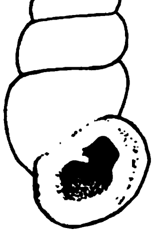

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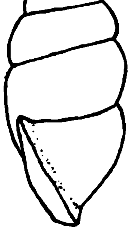

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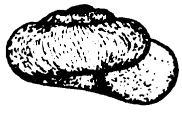

13

GULICK. FOSSIL LAND SHELLS OF BERMUDA.

59.82 : (729.9)

CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL STATION
FOR RESEARCH.

No. 3.

A LIST OF BERMUDIAN BIRDS SEEN DURING JULY AND AUGUST, 1903.

BY HAROLD BOWDITCH.

FROM THE AMERICAN NATURALIST, VOL. XXXVIII. No. 451.
JULY–AUGUST [SEPTEMBER], 1904.

CAMBRIDGE, MASS., U. S. A.
SEPTEMBER, 1904.

A LIST OF BERMUDIAN BIRDS SEEN DURING JULY AND AUGUST, 1903.[1]

HAROLD BOWDITCH.

THE following list comprises those birds which fell under my personal observation on or near the Bermuda Islands between the sixth of July and the twenty-second of August, 1903, the time of my stay at the Bermuda Biological Station. The names of such birds as are included in the Check-list of the American Ornithologists' Union are preceded by their respective check-list numbers, and every effort has been made to bring the scientific names down to date. I wish here to express my thanks to Prof. Edward L. Mark, Director of the Biological Station; Mr. John T. Nichols; Mr. Owen Bryant; Mr. Goodwin Gosling, of Hamilton; and the Messrs. Louis L. Mowbray and R. S. McCallan, of St. George, for their valuable aid in furthering my observations.

70. *Sterna hirundo* (?) Linn. Common Tern.— Terns were seen three times off the north shore, in each case a single individual, but not once was I near enough to make a positive identification. They were in all probability *S. hirundo.*

89. *Puffinus gravis* (?) (O'Reilly). Greater Shearwater.—A. Shearwater-like Petrel (family Procellariidæ) was seen in sight of Bermuda, July sixth; it was probably a Greater Shearwater, although certain identification of this bird and of the two others seen on the same day would not be possible without specimens.

109. *Oceanites oceanicus* (?) (Kuhl). Wilson's Petrel.— A "Mother Cary's Chicken" was seen from the S. S. "Gladisfen" on the "Challenger" bank, about twelve miles southwest of Gibbs' Hill, on the first of August. Identification was impossible, but the bird was probably a Wilson's Petrel. Merriam ('84, p. 284) reports finding a Leach's Petrel, dead, on the

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[1] Contributions from the Bermuda Biological Station for Research. No. 3.

shore at "'Tuckerstown Beach,' May 1, 1881," and says: "The bird is common enough at sea a hundred or two miles from the Bermudas, but I never saw one near the islands."

112. *Phaëthon americanus* Grant. Yellow-billed Tropic Bird; "Long-tail."— The Yellow-billed Tropic Birds were perhaps the most conspicuous birds in Bermuda until the middle of August, when their numbers seemed to decrease. These birds lay one egg with brown markings, in holes in the cliffs, almost always with no attempt at a nest; as they are very close sitters, many opportunities are offered for study at short range. Mr. Owen Bryant found chicks in the "natal down" on Castle Island on June thirtieth. Eggs were found in Harrington Sound as late as July twenty-sixth, and a downy young bird was found on Brangman's Fort on August twelfth.

I was very much interested in observing the change in the plumage of the young "Long-tail," as seen in many specimens. The bird emerges from the egg covered with puffy white down, shaded with gray on the wings, and has a pale grayish bill, gray feet, and gray, unfeathered lores. This "natal down" is changed for a plumage of white, with black spots on the head, wings and back, and one black spot on the end of each tail-feather. The bill is yellowish flesh-color and grayish; the lores are feathered, and the tail-feathers are all of the same length. During the persistence of this plumage, which in being speckled resembles that of the Red-billed Tropic Bird, the bill becomes yellowish orange, the tint which persists throughout life. The fact that I never saw a speckled bird on the wing, but always on the "nest," leads me to suppose that the speckled plumage is exchanged for a plumage indistinguishable from that of the adult bird, before the bird-of-the-year takes flight; and it seems as if the change could not be due to wear, as the bars and spots of black are almost half an inch from the ends of the feathers.

194. *Ardea herodias* Linn. Great Blue Heron.— I saw one of these birds in Tucker's Town Bay, July fifteenth, and another was seen on an island near Hamilton Harbor on the eighth of August. Capt. Savile G. Reid ('84, p. 242), quoting Major Wedderburn, says: "In 1846 the nest of this bird, containing two eggs, was found amongst the mangrove trees at Hungry Bay." This is said to be the only known nest-record.

234. *Tringa canutus* (?) Linn. Knot; Robin Snipe.— A single bird, probably of this species, was seen on July twenty-seventh on Cooper's Island, in company with three other waders, a Turnstone, a Spotted Sandpiper, and a supposed Sanderling. All were rather shy and hard to approach.

248. *Calidris arenaria* (?) (Linn.). Sanderling.—One instance, not a positive identification; Cooper's Island, July twenty-seventh.

263. *Actitis macularia* (Linn.). Spotted Sandpiper.—I have only two days' positive records for the Spotted Sandpiper, namely July twenty-seventh, when I saw two or three on Cooper's Island; and July twenty-ninth, two at Hungry Bay. However, Sandpipers were seen on one or two other days, and were probably the Spotted.

274. *Ægialitis semipalmata* Bonap. Semipalmated Plover: Ringneck.— One instance, a single bird on Cooper's Island, August twelfth.

283. 1. *Arenaria morinella* (Linn.). Ruddy Turnstone.— One record, Cooper's Island, July twenty-seventh.

289. *Colinus virginianus* (Linn.). Bob-white; "Quail."—According to Capt. Savile G. Reid ('84, p. 227) these birds were imported from the United States in 1858 or 1859. My records for them extend from July seventh to August twentieth, seldom more than one in a day. I heard the spring call as late as August tenth, and was told that a brood of young was seen near the Hotel Frascati, where the Biological Station was located, shortly before my arrival in Bermuda.

320b. *Columbigallina passerina bermudiana* (Bangs and Bradlee). Bermuda Ground Dove.— This is one of the common Bermuda birds, being found especially in cultivated areas. It is very tame, allowing one to approach within two yards of it.

428. *Trochilus colubris* (?) (Linn.). Ruby-throated Hummingbird.— On July twentieth, as I was driving along the Middle Road, not far from the Whitney Institute, a Hummingbird flew over my head from among some oleanders. As the Ruby-throat is the only Hummingbird that has been taken in Bermuda (Reid, '84, p. 210), the bird that I saw was probably of this species. On July fifteenth another member of our party (Prof. Albert Mann) saw a Hummingbird in the same neighborhood.

488. *Corvus americanus* Aud. American Crow.— Messrs. Bangs and Bradlee (:01, p. 253) say: ". . . . It is, however, doubtful if the Bermuda Crow is *Corvus americanus.* Its notes are said to be different, more like those of the European Carrion Crow (*Corvus corone* Linn.), a hoarse, raven-like croak.

During the season of 1900–1901, crows were seen but seldom and never more than three together at any one time. They were shy and their notes were not heard distinctly."

I have several records, namely: July seventh, several heard calling on Paynter's Hill; July tenth, two heard calling in the direction of Harrington Sound, from the Flatts; August tenth, a flock of seven seen at close range (but not heard) on the South Shore, about opposite the Devil's Hole; August eleventh, three together, seen and heard on the southern shore of Harrington Sound, west of Patton's Point; and August twenty-first, one heard from the Biological Laboratory on the side of a neighboring hill. In neither flight, appearance, nor voice did any of these crows seem to me to differ from *Corvus americanus*, and I heard their cawing distinctly, especially on July seventh and August eleventh. I was told that there were three Crows' nests on Trunk Island, Harrington Sound, and was shown a nest on Cooper's Island on July twenty-seventh, said to have contained young birds earlier in the season.

593. *Cardinalis cardinalis* (Linn.). Cardinal Grosbeak; Red-bird.—The "Red-bird" is one of the most abundant of the residents, and I have an almost uninterrupted series of daily records from July seventh to August twenty-second, my entire stay, the single exception being on August first, which was spent on the "Challenger Bank," twelve miles from shore. At Hungry Bay I saw a Cardinal's nest containing three or more young birds, on July twenty-ninth, a late date, for Reid says ('84, p. 201), "As a rule, the two clutches of eggs are deposited about April 10th, and May 30th, respectively." Moseley ('79, p. 25) alludes to the fact that it is an introduced species, and Ridgway says (:01, p. 674), "the species is said to have been *introduced* from the eastern United States"; the date I am unable to determine.

Passer domesticus (Linn.). House Sparrow; "English" Sparrow.— Reid wrote in 1877 ('84, p. 196)[1] of two importations from New York, one "a few years ago," the second in 1874, and says, "I have no doubt they will increase and multiply after their manner, and in time become as much a nuisance as they are now a curiosity." This prophecy has been fulfilled, and I am told that the "English" Sparrows breed in Bermuda at all seasons. The Sparrows are interesting in one respect, namely, the fact that the adult birds, and especially the females, are noticeably lighter and more yellowish than the United States birds. That this is due to bleaching is proven by a specimen taken by my friend, Mr. Nichols. This bird is an adult female, in which the light colored, worn-out tail feathers are being replaced by a new set of typical dark ones.

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[1] Reprinted from 1877.

Carduelis carduelis (Linn.). Goldfinch.—Reid ('84, pp. 196–197) says, "I observed a single specimen of the European Goldfinch, *Carduelis elegans*, near Harrington Sound, in April, 1875; it was very wild, and I could not get near it, but I imagine it must have been an escaped prisoner." This bird is now common in Bermuda, and I did not find it at all hard to approach, in spite of the fact that Bangs and Bradlee (:01, p. 256) state that it "is exceedingly shy and wary." By far the largest flock that I saw was at the Flatts, on August tenth, and contained about thirty birds. On June twenty-ninth Mr. Owen Bryant found a newly built nest of the Goldfinch on Trunk Island, Harrington Sound; it was in a cedar, some twenty-five feet from the ground and six or seven feet from the trunk of the tree. On July sixth it contained four eggs.

611. *Progne subis* (?) (Linn.). Purple Martin.—On August fourteenth, while between Coney Island and the Ferry Reach, I saw two Martins flying past the Martello Tower, southward. I was unable to determine the species, whether Purple or Cuban, but as the range of the Cuban Martin is, according to Chapman ('95, p. 320), "Southern Florida south to Cuba and probably Central America," the birds were in all likelihood Purple Martins. Reid ('84, p. 190) states that this bird "has only .... appeared on one occasion, during the 'entrada' of September, 1849, when it was numerous." I looked this matter up in the "Natural History of the Bermudas," a collection by Miss H. T. Hurdis of scattered notes by her father, John L. Hurdis. His

only records of specimens fall in September, 1849, but he records martins seen by other people three times, viz.: August, 1847 (p. 26); September 19th, 1850 (p. 193); and April 24th, 1851 (p. 212).

631b. *Vireo noveboracensis bermudianus* (Bangs and Bradlee). Bermuda White-eyed Vireo; "Chick-of-the-village."— This bird ranks with the Cardinal and the Catbird in point of numbers; everywhere that one goes, he hears its characteristic song, translated into "chick-of-the-village" by the negroes. Bangs and Bradlee (:01, p. 253) say, "The iris in *V. bermudianus* is *white* as in *V. noveboracensis*, and not "brownish, brownish gray, or gray," as stated by Capt. Reid. This seems to me to be a very hasty conclusion, as I have never seen a Bermuda Vireo with a pure white eye. The birds are very tame and familiar, and I made it something of a point to look at the iris whenever a good opportunity offered, with the result that I saw just two specimens with "dirty white" irides, and these had every appearance of being young birds. The irides of all the other birds of which I took note were dark.

Reid ('84, p. 192) says, "It is on record that the newly fledged young of this species have been found entangled in the meshes of the web of the 'silk' spider, *Epèira* [Epeira] *clavipes*. These webs are of great size and strength, extending for many feet between adjoining cedars, and the number of them among the woods in summer and autumn is almost incredible. In all my rambles, however, I never met with an instance of poor little Vireo having walked into Epëira's parlor."

On the twenty-ninth of July I saw, at the edge of the mangrove swamp at Hungry Bay, a Vireo with a large mass of cobweb on the side of its head, completely covering the right eye. The left eye only was used, which necessitated the bird's turning on its perch in order to watch us, instead of simply turning its head.

704. *Galeoscoptes carolinensis* (Linn.). Catbird; "Blackbird."— Extremely common throughout the islands. During my stay in Bermuda I did not once hear the "mew" which gives the Catbird its name, and the song and the other notes of the Bermuda Catbirds sounded to me not quite identical with those of United States birds.

766. *Sialia sialis* (Linn.). Eastern Bluebird.— A very common bird. Bangs and Bradlee (:01, p. 255) state that the Bluebird is migratory as well as resident, so that "possibly some of" the migrants "remain and breed and thus counteract any tendency to vary that the island birds might develop if wholly cut off from the main body of the species." Reid ('84, p. 175) says of the nests, "I have found them commonly in holes in old quarries or roadside cuttings; also in crevices of walls; in rocks, even when some little distance from the shore; in holes in trees; on the branches of trees; in stove and water pipes; in calabashes, boxes, etc., hung up for them in the verandas of houses, ... and in several other curious situations."

On July tenth Mr. Owen Bryant found a Bluebird's nest containing three young birds, built in the capstan of an old wreck near Coney Island. On the twenty-sixth of July Mr. John T. Nichols and I found some holes in a bank of sand, part of one of the cliffs nearly due north from the Devil's Hole, Harrington Sound; they were some four or more inches in diameter and a foot and a half to two feet deep, and two of them contained nests of soggy vegetable materials, one of which had in it a couple of bad eggs, probably Bluebirds'. This seemed to us a strange nesting site for the bird which we always associate with the hollow limb of an old apple tree.

Besides the twenty-one birds listed above, the following were reported to me:

On July twenty-third Mr. Leon J. Cole saw a Tattler (*Totanus*), probably *melanoleucus*, at St. David's.

During July a large Hawk was seen by various members of the Bermuda Biological Station. His identification as a *Buteo* was all but complete.

On August sixteenth Mr. Louis L. Mowbray told me of a "Snowy" Owl ~~(*Nyctea nyctea*)~~ Strix which had been seen on the afternoon of the previous day, in the Devonshire marsh. Swallows (probably Barn Swallows, *Hirundo erythrogastra*) were reported common.

INDEX OF SCIENTIFIC NAMES.

Page.
Actitus macularia 557
Ægialitis semipalmata 557
Ardea herodias 556
Arenaria morinella 557
Buteo 561
Calidris arenaria 557
Cardinalis cardinalis 558
Carduelis carduelis 559
Colinus virginianus 557
Columbigallina passerina bermudiana 557
Corvus americanus 558
Galeoscoptes carolinensis 560
Hirundo erythrogastra 561
Nyctea nyctea 561
Oceanites oceanicus 555
Passer domesticus 558
Phaëthon americanus 556
Progne subis 559
Puffinus gravis 555
Sialia sialis 561
Sterna hirundo 555
Totanus melanoleucus 561
Tringa canutus 557
Trochilus colubris 557
Vireo noveboracensis bermudianus 560

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[1] Note.— This paper by A. H. Verrill, seems to have been overlooked by the author.— E. L. Mark.

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1. Cole, L. J. — Pycnogonida collected at Bermuda in the Summer of 1904. Proc. Bost. Soc. Nat. Hist., **31** (8) : 315–328, pls. 20–22. July, 1904.
2. Gulick, A. — The Fossil Land Shells of Bermuda. Proc. Acad. Nat. Sci. Phila., **56** (2) : 406–425, pl. 36. June, 1904.

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4. **Coe, W. R. — The Anatomy and Development of the Terrestrial Nemertean (Geonemertes agricola) of Bermuda. Proc. Bost. Soc. Nat. Hist., 31(10) : 531–570, pls. 23–25, Nov., 1904.**

No. 10.—THE ANATOMY AND DEVELOPMENT OF THE TERRESTRIAL NEMERTEAN (*GEONEMERTES AGRICOLA*) OF BERMUDA.[1]

BY WESLEY R. COE.

CONTENTS.

	PAGE.		PAGE.
Introduction	531	Ovogenesis	546
Generic and specific diagnoses .	533	Spermatogenesis . . .	549
General anatomical peculiarities	538	Reproduction	551
Proboscis	538	Copulation	552
Body walls and integument	540	Development	554
Cephalic glands . . .	541	Nervous system . . .	557
Alimentary canal . .	542	Cerebral sense organs .	557
Blood vessels . . .	542	Cephalic glands . . .	558
Nephridia	543	Alimentary canal . .	559
Nervous system and sense organs	544	Proboscis	562
Reproductive organs . . .	545	Habits	566
		Bibliography	569

INTRODUCTION.

WHEN the Challenger expedition visited the Bermuda Islands, in June, 1873, von Willemoes-Suhm, a member of the party, collected a number of nemerteans living in company with earthworms and other terrestrial forms on the shores of Hungry Bay. These nemerteans he described under the name of *Tetrastemma agricola* in a paper published in the Annals and magazine of natural history, for 1874 (p. 409). This paper contains a general account of the anatomy and habits of the worms, although a number of anatomical peculiarities, such as the form of the stylet basis and position of the mouth were incorrectly described. The specimens were lost during the voyage, so that Hubrecht, who worked up the Challenger material, was unable to study in detail the anatomy of the species.

Apparently no further specimens were collected until Prof. A. E. Verrill and party visited the islands in 1898 and 1901, when numerous individuals were obtained in the original locality, but of much larger size than those found by the Challenger party. These worms occurred not only near the shore but also well up on the side of the hill where the soil was comparatively dry. On his return to New Haven, Professor Verrill very kindly brought a number of living specimens to the writer and these were kept for some weeks in the dry earth in which they came from Bermuda, a few drops of water being added from time to time to prevent complete desiccation. These specimens were subjected to rough treatment by being placed on glass slides on numerous occasions and examined under the microscope. They perished eventually, evidently from lack of a supply of suitable food.

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[1] Contributions from the Bermuda biological station for research. No. 4.

It was partly with a view to further investigations on the anatomy and development of this form that the writer visited the Bermudas in June and July, 1903.[1]

At this time an abundance of material was obtained, for the species was found to be widely distributed on the islands, occurring on the north as well as on the south shore, and was common along the borders of several of the larger mangrove swamps. At this season of the year the worms were found to be sexually mature, their bodies being crowded either with ripe eggs and spermatozoa or with embryos in all stages of development, for the species proves to be viviparous, giving birth to young worms of comparatively large size fully provided with nearly all the organs of the parents except the reproductive glands. The general course of development of these embryos could be followed with the greatest ease by making serial sections of the adult worms in which they were contained.

Examination of the sexual glands of numerous individuals showed many with these embryos in various stages of development, while others were provided with ova only. Still other specimens of small size were completely filled with ripe spermatozoa. Moreover, a number of individuals — the largest specimens collected — had nearly mature embryos and in addition small gonads of both kinds of sexual products. In some of these latter the spermatozoa were fully formed.

The species has therefore a peculiar interest because of the fact that it is both hermaphroditic and viviparous and presents such a great variety of conditions in regard to the development of its sexual products. Willemoes-Suhm in his original account of the species expresses the opiniòn ('74, p. 410) that it is viviparous, although no observations were made in support of this view.

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[1] The writer is greatly indebted to Prof. E. L. Mark and Prof. C. L. Bristol for the excellent facilities afforded by the newly established Bermuda biological station for research.

GENERIC AND SPECIFIC DIAGNOSES.

The general anatomy of the species does not differ greatly from that of other Hoplonemertea and agrees very closely with the account given by Böhmig ('98) for *Geonemertes chalicophora*, so that a detailed discussion of its anatomical and histological structure is unnecessary; yet the species presents interesting peculiarities in regard to a number of points of internal structure, and these will be briefly described. The external form, color, habits, and development will be treated at greater length.

Geonemertes Semper.

Zeit. f. wiss. zool., vol. 13, p. 559, 1863.

The genus includes all known terrestrial nemerteans and may be characterized as follows: body long and slender, of comparatively small size, usually from 15 to 50 mm. in length, occasionally 150 mm.; proboscis pore subterminal; esophagus opens into rhynchodaeum either shortly in front of brain (as in *G. agricola*) or much nearer the tip of snout (as in *G. chalicophora*); proboscis sheath extends very nearly or quite to posterior end of body; proboscis large compared with size of worm, with well developed central stylet and basis and two or four pouches of accessory stylets, with normally more than 10 nerves in all forms in which the number is accurately known; intestinal caeca usually extend forward nearly to brain; intestinal lobes metameric and prominent; nephridia in at least two of the species diffused, extending from brain region far back into the body (in one species to posterior end of body), with numerous efferent ducts; cephalic glands very voluminous, extending posteriorly behind brain; cerebral sense organs either small, and situated anterior to brain, or larger, and extending beneath the brain lobes; eyes vary in number, being commonly 4, in some species 6, and in others numerous; reproductive organs present great variations, some species are supposedly of separate sexes, others are certainly hermaphroditic, and at least one is viviparous.

Terrestrial nemerteans are found in a great variety of situations, some species living near or on the seashore, or in comparatively dry inland soil, while others occur beneath stones and rotting wood or beneath the dead bark of trees in damp places in warm countries, or are imported into greenhouses in other lands. As a rule the worms do not burrow, but lie beneath objects for protection. They are widely distributed in tropical and subtropical regions, occurring principally in islands: Australia, New Zealand, Tasmania, Pewlew (Palao) Islands, New Guinea, Rodriguez Island, Bermuda Islands.

Up to the present time eight species of terrestrial nemerteans have been described, all of which apparently belong to the genus Geonemertes. They are distributed as follows: —

G. palaensis Semper. Pewlew Islands.
G. agricola (Willemoes-Suhm) Bürger. Bermuda.
G. rodericana (Gulliver) Bürger. Rodriguez Island.
G. chalicophora Graff. Introduced into greenhouse at Frankfurt, Germany; probably introduced from Australia.
G. australiensis Dendy. Australia.
G. novae-zealandiae Dendy. New Zealand.
G. graffi Bürger. New Guinea.
G. micholitzi Bürger. Samarai, Queensland.

The more important specific and anatomical peculiarities of these eight species may be represented by the following comparative table of anatomical characters: —

	Size.	Color.	Ocelli.	No. of pouches with accessory stylets.	Proboscidial nerves.	Sexes.	Frontal organ.	Other peculiarities.
G. palaensis	40–50 mm.	Reddish, dark brown stripe.	6	2–4	19–21	United.	Conspicuous.	
G. agricola	15–150 mm.	Whitish, brownish, or orange.	4	2	13–15	United; viviparous.	Highly developed.	Cerebral sense organ small, in front of brain.
G. rodericana	27–75 mm.	Dark green with fine white lines.	4 (?)	4		Separate.		Nerve from dorsal ganglion accompanies lateral nerve.
G. chalicophora	12 mm.	White, reddish anteriorly.	4	2	12	See footnote.[1]	Small or wanting.	Calcareous bodies in integument and parenchyma.
G. australiensis	40 mm.	Yellow, brown, or orange.	Numerous.	2	18[2]	Separate; male smaller; oviparous.	Small or wanting.	Glandular portion of cerebral sense organ extends behind brain.
G. novae-zealandiae	37–53 mm.	4 purplish brown stripes.	4	4		Separate (?); male not known.		
G. graffi	150 mm.	4 dark brown stripes separated by whitish lines.	4	2	23	Separate (?); male not known.	Very large.	Cerebral sense organ large, beneath brain; nerve from dorsal ganglion accompanies lateral nerve.
G. micholitzi	150 mm.	4 dark brown stripes.	4	2	23		See footnote.[3]	Cephalic glands enormously developed.[3]

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[1] Stated by Graff ('79) to be hermaphroditic, although Böhmig ('98) examined Graff's specimens and found ova only, and therefore concluded that the species is of separate sexes, the males as yet being unknown.

[2] Shown in Dendy's drawing ('92, pl. 9, fig. 16), although not stated definitely in text.

[3] Bürger ('96, p. 274) states that the characters of *G. micholitzi* are strikingly similar to those of *G. graffi* except that (1) the cephalic glands are so enormously developed that they extend far behind the brain and fill the parenchyma almost completely, and (2) the lateral nerves lie rather near together on ventral side of body.

Geonemertes agricola (Willemoes-Suhm).

Tetrastemma agricola Willemoes-Suhm, Ann. mag. nat. hist., vol. 13, p. 409, pl. 7, fig. 1–3, 1874.

Tetrastemma agricola Moseley, Notes by a naturalist on the Challenger, pp. 26, 27. London, 1879.

Tetrastemma agricola Hubrecht, Challenger reports, vol. 19, p. 23, 1887.

Neonemertes agricola Girard, Ann. sci. nat., zool., ser. 7, vol. 15, p. 238, 1893; Joubin, Les némertiens, Fauna Française, Paris, 1893.

Geonemertes agricola Bürger, Fauna und flora des Golfes von Neapel, monogr. 22, p. 557, 1895.

Tetrastemma agricola Verrill, Trans. Connecticut acad. sci., vol. 11, p. 847, 1901–02.

Body slender, flattened, of almost uniform width throughout. Head when extended somewhat broader than body although not distinctly demarcated, widest in the vicinity of the ocelli and narrowing gradually toward tip of snout. After preservation, or when contracted, head is continuous with body and of uniform width, being sharply truncated anteriorly and often very slightly bilobed in front. Esophagus opens into rhynchodaeum immediately in front of brain and the latter into a subterminal atrium which is not sharply marked off from rhynchodaeum. On each side of atrial, or rhynchodaeal, opening is a rather conspicuous horizontal furrow extending backward for some distance on the lateral border of snout. An indistinct vertical groove passes through the rhynchodaeal opening in preserved specimens. An inconspicuous V-shaped marking or groove is situated symmetrically on dorsal side of posterior portion of head and extends antero-laterally nearly to ventral surface. When head is well extended in life this groove lies between the anterior and posterior pairs of ocelli, but after preservation or when head is strongly contracted it lies immediately posterior to ocelli.

Esophageal and intestinal regions of nearly uniform width; in life subcylindrical, but after preservation about one and one half times as wide as thick; tapering gradually to narrow posterior extremity (pl. 23, figs. 1, 2). When killed in formalin posterior portion of body usually coils dorsally like a short watch spring while the anterior half of body remains nearly straight. This gives specimens preserved in formalin a very characteristic appearance. In this species the muscular contractions are evidently much stronger in the dorsal than in the ventral portion of the body, whereas in many nemerteans which coil ventrally when killed, the reverse condition apparently exists. It seems probable that the contraction of the powerful longitudinal muscles of the proboscis sheath is largely responsible for the dorsal coiling in Geonemertes and also in the species of Amphiporus and Drepanophorus which exhibit the same peculiarity.

Size.— Willemoes-Suhm describes the specimens which he obtained as about 35 mm. long and 2 mm. wide, while Verrill (:**01**-:**02**, p. 847) found individuals measuring 150 mm. in length when fully extended, but of very slender proportions. A hundred or more individuals which the writer examined in June and July, 1903, were only from 15 to 35 mm. in length, although some of them had their bodies distended with mature sexual products or with embryos in all stages of development. Verrill's larger specimens were collected in the month of April and contained nearly mature ova. Although the species is normally hermaphroditic, individuals occur which contain only spermatozoa, and these individuals are all of small size. The larger worms may contain both eggs and spermatozoa (which are commonly formed in separate gonads) as well as the developing embryos.

As stated below, it seems probable that the majority of individuals become sexually mature in the later spring months, their embryos developing at the expense of the tissues of the parent which, after giving birth to its very large and very numerous progeny, again becomes a worm of much smaller size. This would perhaps account for the small size of the specimens found by Willemoes-Suhm in June and by the writer in midsummer. Individuals found near high-water mark are commonly much smaller than those living farther from the seashore. Diameter of body 0.5 to 3 mm.

Color.— The species presents a great range of variation in color. The small specimens collected by Willemoes-Suhm were milk white, while the much larger ones taken by Verrill (:**01**-:**02**, p. 847) were dusky brown, grayish or smoky brown dorsally, with the ventral surface paler. The largest specimens collected in the summer of 1903 were greenish brown, olive or smoky brown dorsally, with a slightly paler median dorsal band in the anterior portion of the body; ventral surface very pale gray or whitish. In the anterior portion of the body the brown color of the dorsal surface does not reach the lateral margins of the body, leaving the tip of snout and lateral borders of head and anterior portion of esophageal region of the same whitish color as that on ventral surface.

Other specimens are orange anteriorly and yellowish in intestinal region, with dark reddish brown or dark gray intestinal canal (pl. 23, fig. 2). Still others are rosy flesh color with a tinge of gray dorsally and colorless, or whitish, ventrally (pl. 23, fig. 1). Other individuals exhibit various shades of ochre and gray from the deeper tints to very pale gray, while the very small worms are usually nearly white, or grayish white, or almost colorless.

The brain is rosy or orange and often rather conspicuous; the eggs are yellowish, and the masses of spermatozoa whitish, affecting the color of the body in sexually mature individuals. The proboscis is very pale, or colorless, with a whitish or yellowish tinge.

Most of the larger, more deeply colored individuals had their bodies filled with large embryos in the month of July. Solid masses of secretion scattered in the integument commonly give the appearance of very fine whitish dots covering the body.

Ocelli.— The two ocelli of the anterior pair are nearer together and of larger size than those of the posterior pair, and of more regular outline. The two of each side are commonly nearer together than those of either the anterior or the posterior pairs. In section the ocelli are found to be situated rather deep in the tissues of the head (fig. A, p. 540). Each ocellus is provided with a large pigment cup, sometimes nearly 0.1 mm. in diameter, which faces the lateral aspect of the head. From this cup a conspicuous nerve leads to the dorsal brain lobe.

General Anatomical Peculiarities.

Proboscis.— The rhynchocoel extends nearly, although not quite, to the posterior end of the body. Proboscis of large size, when partially extruded commonly equal in diameter to the body itself; attached to tissues of head in anterior portion of brain region. Esophagus opens into rhynchodaeum directly in front of brain.

The number of proboscidial nerves is somewhat variable, the majority of individuals having 13 ; a smaller number have 15, while one specimen examined had 14. Another, which must be considered as somewhat abnormal, had only 10 distinct nerves with possible indications of 4 others. Muscular and epithelial layers of proboscis as in related forms.

Willemoes-Suhm describes the two pouches of accessory stylets, and states that the shape of the basis of the central stylet is an indication of the sex of the individual — the male having a pear-shaped basis with rounded posterior end, while the corresponding portion of the basis in the female is abruptly truncated with "sharpened angles." The fact that the animals prove to be hermaphroditic is sufficient evidence that the angular form of the basis in the supposed female individual must have been abnormal or compressed out of its natural shape.

A large number of proboscides examined showed invariably two pouches of accessory stylets, with from three to six or more slender stylets in each, the usual number being five or six. The accessory stylets when mature measure from 0.08 to 0.095 mm. in length. The head of each stylet is usually inconspicuously divided into four or sometimes five lobes by an equal number of very slight constrictions (pl. 23, fig. 4). Similar lobes are figured by Dendy ('92) for *G. australiensis*. A further peculiarity of the stylet is the presence of a very minute and inconspicuous triangular or wedge-shaped structure of a clear and highly refractive nature in the body of the stylet at the point of union of body and head. The acute angle of this wedge usually points into the head of the stylet, and thus in a direction reverse from that of the body of the stylet itself. This wedge-shaped structure could not be distinguished in all cases, although it was generally present in both central and lateral stylets. A similar structure which occurs in the stylet of *G. australiensis* is described by Dendy ('92, p. 98) as a quadrangular space "frequently of a black appearance, owing doubtless to the presence of air within it."

The central stylet (pl. 23, fig. 3) is perfectly similar in size, shape, and structure to the reserve stylets. It is of about the same length as its basis, or slightly longer. The basis is pear-shaped with rounded posterior margin, and perfectly symmetrical with respect to its longitudinal axis. It is about one and one half times as long as its greatest width. Several bases measured from 0.075 to 0.09 mm. in length and from 0.045 to 0.06 mm. in greatest width.

As described below, the stylet apparatus, including both the cen-

The principal function of this large tube is clearly to discharge the secretions from the cephalic glands in which it terminates. These secretions evidently pass into the duct by being forced between the cells which constitute its lining. The secretions from those cephalic glands which are situated behind the posterior end of the frontal organ must be passed forward through temporary ducts formed between the gland cells until the tube of the frontal organ is reached.

Besides the true cephalic glands there occur scattered through the tissues of the head numerous other gland cells which are conspicuous because of their granular secretion, which commonly stains very differently from that of the cephalic glands. These gland cells lie mainly near the surface of the head upon which they discharge their granular secretion through the overlying muscular and basement layers. They are evidently merely specialized integumentary glands which have sunk beneath the basement membrane.

Alimentary canal.— The esophagus (pl. 24, fig. 13) leaves the rhynchodaeum immediately anterior to the ventral brain commissure as a narrow tube which passes beneath the commissure. Directly posterior to the brain it merges into a large chamber, the stomach, with highly columnar, ciliated epithelium and convoluted walls. This conspicuous stomach was thought by Willemoes-Suhm ('74, p. 410) to be the mouth. Behind the stomach the narrow pylorus passes backward directly beneath the proboscis sheath for a considerable distance before opening into the dorsal wall of the intestine. From the pyloric opening a broad intestinal caecum with numerous lateral diverticula extends forward nearly to the brain. The intestine exhibits conspicuous metameric pouches. The anus opens by a small pore on the dorsal side of the posterior extremity of the body.

Blood vessels.— The blood vascular system offers few deviations from that of most related species, although it has no direct connection with the nephridial canals such as Dendy ('92) describes for *G. australiensis.* Böhmig ('98, p. 503) describes certain large cells found in or beneath the basement layer of the blood vessels in *Geonemertes chalicophora* as acting in the nature of valves to regulate the direction of the flow of blood in the vessels. Similar cells occur in *G. agricola*, *G. australiensis*, and in numerous other Hoplonemertea of various genera, although such an interpretation of their function is not wholly satisfactory. It should be noted that they occur with equal abundance about the large lateral vessels which are probably under no circumstances completely closed at any point, so that their action as valves would be out of the question. Observations on the circulation of the blood in the living worms demonstrate the fact that the blood flows backward and forward in the same vessel at different times, the course of the flow apparently depending wholly upon the state of muscular contractions of the body and movements of its different portions. Moreover the substance of the cell becomes deeply colored with the same reagents that stain the secretions of various glands in the body. It therefore seems probable that they are simple glandular cells whose function is to pour their secretions into the blood vessels. Dendy ('92) figures these cells accurately, but probably falls into error in stating that the smaller vessels along which they occur are nephridial tubules which open into the larger blood vessels.

The dorso-median vessel does not enter the walls of the proboscis sheath at any part of its course, but extends from the ventral brain commissure to the posterior end of the body directly beneath the proboscis sheath. In the intestinal region there are paired metameric anastomoses with the lateral vessels.

Nephridia.—Very numerous nephridial canals of small size ramify through the tissues of the head. Back of the brain these canals unite into one or more branched longitudinal canals which extend at least as far back as the posterior end of the esophageal region. In *Geonemertes chalicophora*, Böhmig ('98, p. 512) found the nephridial canals throughout the whole length of the body, and it is possible that this may also be the condition in the species at hand. If so, the canals are all of small size in the posterior half of the body, and much less conspicuous than in the head and esophageal region.

In the anterior half of the body the nephridial tubules branch profusely both above and below the lateral nerves, the finer branches terminating in "flame cells" situated in the body parenchyma, as Bürger ('91) has so fully described for Drepanophorus and other Hoplonemertea.

Dendy ('92) observed these flame cells in *G. australiensis*, but apparently overlooked the nephridial canals with which they are connected, and was unable to find any efferent nephridial ducts contained mature and active spermatozoa. In these cases the spermaries contain but a small number of sperm mother cells, spermatocytes, and spermatozoa, and are not more than one third or one fourth as large as the diameter of one of the embryos in the body (pl. 23, fig. 6), and yet they are actively engaged in the formation of spermatozoa.

Finally, we meet with worms of much smaller size than either the females or the hermaphrodites with embryos and these are filled to the point of rupture with distended spermaries. These smaller individuals must therefore be looked upon as representing the purely male condition. In these forms no trace of eggs or embryos can be observed.

The small males are much less numerous than individuals with eggs or embryos, and in this respect the species agrees with *G. australiensis.* Indeed, in several species of the genus, as in *G. chalicophora* (according to Böhmig, '98), *G. graffi*, and *G. novaezealandiae*, the males are as yet unknown, individuals supposed to be females being the only known representatives of the species.

The reproductive organs are further complicated by the presence of undifferentiated sexual glands, which occur in some individuals in addition to the gonads which form ova only or spermatozoa only. These undifferentiated glands form both kinds of reproductive elements in a manner similar to that which has been described by Montgomery ('95) for Stichostemma. As shown in figure 7 (pl. 23) such indifferent gonads apparently form and discharge their spermatozoa first and develop their ova afterward. These gonads are therefore protandric, and it is very likely that individual worms occur in which this is the case with all the gonads of the body.

After the discharge of the spermatozoa the ova in the same gonads complete their development and the individual might then be looked upon as purely female. This is likewise the case in *Stichostemma eilhardi*, as described by Montgomery ('95).

Ovogenesis.—In the development of the ovaries the young sexual gland is composed of a considerable number of cells, all of which seem to be of the same size and appearance. At a somewhat later stage three or four of these cells are decidedly larger than the others, and of these larger cells either one or two considerably surpass the others in size. Finally a single cell becomes distinguished from the others by its larger size and content of yolk spheres, and this becomes the only ovum to arrive at maturity, except in the comparatively few cases in which the gonad matures two ova.

Previous to the maturity of the ova, a distinct duct is formed which leads from the ovary to the exterior of the body. This duct usually opens above the lateral nerves, and through it spermatozoa from another individual gain access to the contained ovum. The duct then closes up and the developing embryo is isolated from the outer world.

If two ova be present, it sometimes happens that only one is sufficiently mature to be fertilized, so that such gonads later contain in addition to the single embryo an ovum which is unable to develop because the closing of the duct leading from the exterior of the body to the ovary has prevented the entrance of other spermatozoa at the proper season. Such an ovum eventually degenerates, and its substance is absorbed by the other tissues, although it may remain until the embryo developing from its sister cell has become nearly mature.

The details of the developmental processes concerned in the formation of the mature ovum agree in most respects with the accounts given by Montgomery ('95) and Böhmig ('98) for Stichostemma.

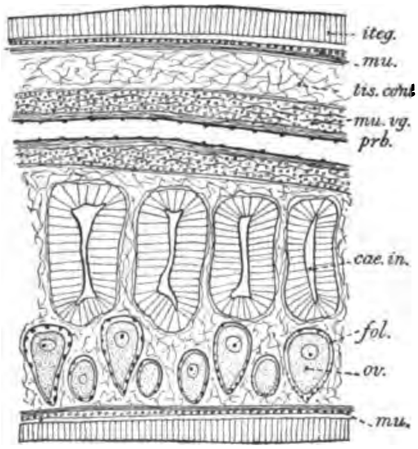

FIG. B.—Portion of longitudinal section of body of a worm with nearly mature ova, showing the relations of the genital pouches, each of which contains a single ovum (*ov.*) surrounded by a thin follicular epithelium (*fol.*), and the less numerous intestinal caeca (*cae. in.*); *mu. vg. prb.*, muscular layers of proboscis sheath; *tis. co'nt.*, connective tissue of body parenchyma. × 55.

The youngest gonads occur as small clusters of oval cells situated in a longitudinal row in the body parenchyma immediately above the lateral nerve on each side of the body. As a rule about two gonads are situated between each pair of intestinal lobes (fig. B), although by their further growth and enlargement adjacent gonads grow past each other so that when mature a transverse section of the body may cut through two or more of these sexual glands.

In the young gonad all of the cells seem to be exactly alike in size and general appearance, but they soon exhibit variations both in size and in structure, so that three types of cells are recognizable (pl. 23, figs. 7, 8), young ova, yolk cells, and follicular cells.

The follicular cells are flattened and form a thin layer within the wall of the gonad, constituting an investment for the egg when nearly mature; they also furnish the cells which form the duct through which the sexual gland is connected with the exterior of the body. The follicular cells at the side of the gonad nearest the body wall become somewhat spheroidal in form and collected into a small cluster. They then grow outward into the overlying muscular layers of the body wall to form a sharply pointed duct, lined with flattened cells, which projects outward as far as the basement layer of the integument (as shown for the spermary, pl. 25, fig. 26). The duct is formed to this extent at a very early period in the development of the ova, and remains in this condition until the single ovum developing in the gonad becomes well advanced toward maturity, when it completes its growth to the exterior, opening in all cases dorsal to the lateral nerve.

The yolk cells (*ov'.*) are apparently merely egg cells which for some reason become aborted at an early period. They are rather numerous in each young ovary, and grow to a size several times that of the largest follicular cells. They become crowded with yolk granules and pressed closely against the wall of the developing ovum. To all appearances the cell membranes separating ovum and yolk cells break down and the latter are absorbed directly into the substance of the developing ovum. The whole substance — cytoplasm, yolk, and nucleus — of the yolk cell seems to be thus absorbed by the ovum.

There may be several large cells in the young ovary which are distinguished by a more homogeneous cytoplasm from the yolk cells with which they are surrounded. These cells increase rapidly in size and are recognizable as young ova. Eventually, however, all save one, or rarely two, of these ova cease their growth and become disintegrated to furnish food materials for the surviving cell. The mature ovary therefore usually contains but a single large ovum (pl. 23, fig. 8).

This ovum is surrounded by the flattened follicular epithelium of the gonad to which it remains attached for some time at its broader end. It then breaks off and lies free in the ovary, which has previously formed its duct to the exterior. The entrance of a sperm cell from another individual into the ovary fertilizes this egg cell, which then develops into an embryo, while the duct to the exterior of the body closes up, as described above.

The mature eggs measure about 0.35 to 0.45 mm. in diameter. Compared with the diameter of the body of the worm they are extremely large, being in many instances from one third to one half as great as the width of the body. Consequently they are arranged in a single row on each side. In the stained sections of the body they are conspicuous even to the unaided eye. They have a pale yellow color in life. Each egg is surrounded with a delicate membrane of follicular cells and crowded with spherical yolk granules of various sizes, some of which are as much as 0.013 mm. in diameter.

In *G. australiensis* the eggs are nearly one third as large as the diameter of the body of the worm, and do not all mature at the same time. They are fertilized within the body as in *G. agricola*, but are deposited before cleavage. The spermatozoa may remain alive for some time after their entrance into the ovary and may fertilize an ovum which matures some days, or perhaps weeks, later. In this way clusters of fertilized eggs may be deposited at intervals of a week or more. It seems probable that in *G. agricola* a portion of the eggs may likewise mature before the others, for both eggs and embryos in the body exhibit considerable variation in size.

Spermatogenesis.— In the sexual glands which are to form both ova and spermatozoa the latter develop out of the undifferentiated germinal cells which make up the substance of the ovo-testis. As stated above, the spermatozoa usually mature and are discharged before the maturity of the ova in the same gonad. The course of development of the spermatozoa is apparently the same whether they are formed in an ovo-testis or in special gonads which develop spermatozoa only.

In the young spermary comparatively large cells only are present. These divide many times to form the last generation of spermatogonia, which by two divisions give rise to the spermatids.

In spermaries which are approaching maturity, as shown in figure 26 (pl. 25), it is easy to distinguish three kinds of cells in addition to ripe spermatozoa and the follicular cells. These are the spermatogonia, the spermatocytes, and the spermatids. Each kind of cell is collected into clusters in different portions of the gonad (pl. 23, fig. 9; pl. 25, fig. 26).

The last generation of spermatogonia (*sp'go.*), or primary spermatocytes, is distinguished by having large, oval nuclei and comparatively little cytoplasm. The nuclei have a very distinct network of chromatin, although the actual number of chromosomes in the dividing cell has not been determined.

The secondary spermatocytes (*sp'go'.*) have very sharp nuclei and distinct cell membranes, and are naturally considerably smaller than the cells from which they arise. They divide to form the spermatids, which are distinguished by their small size and the eccentric position of the nuclei. Each spermatid is doubtless transformed into a spermatozoon, although the details of the process have not been observed.

The follicle cells (*foll.*) form the lining to the spermary (pl. 25, fig. 26) and the duct by which the mature spermatozoa are discharged. They are perfectly similar to those of the ovaries, which have been described above. The duct leading from the spermary to the surface of the body is formed as far as the basement layer of the integument at an early period, but does not penetrate to the surface of the integument until most of the spermatogonia have divided up into spermatocytes and these have been transformed into spermatozoa.

In the case of the small spermaries which develop at the time when the body of the worm is crowded with developing embryos it seems doubtful whether in many instances the spermatozoa are discharged at all. They develop at a time when the tissues of the body are taxed to their utmost to furnish nourishment for the embryos. Furthermore it is uncertain whether they could be of use if they were discharged after the birth of the embryos, for it is not known whether any ova mature so late in the season. On the other hand the possibility remains that after the discharge of the mature embryos the body of the worm decreases very greatly in size, and that in this much smaller body the spermaries continue their development to such an extent as to again distend the body with sexual products, but this time with spermatozoa. This would, perhaps, account for the appearance of the pure males of small size at the same time that other individuals are carrying embryos.

In order to account for the great diversity of conditions occurring in the sexual phases observed, it seems necessary to assume: the appearance of (1) large females, and perhaps smaller males, in the earlier part of the reproductive season; (2) hermaphroditic forms, appearing somewhat later, some of which first discharge their spermatozoa and subsequently develop the ova which give rise to embryos within the body; (3) hermaphroditic forms which mature eggs and embryos before the discharge of the spermatozoa, then in part become transformed into (4) small males with large spermaries, and in part form (5) separate gonads, some of which contain spermatozoa that mature the same season, others ova that remain undeveloped until the following year, the individual then being again recognized as (1) a female form. Careful study of the worms throughout all seasons of the year is needed to determine with certainty the exact significance of all the sexual conditions observed.

REPRODUCTION.

As has been stated above, the species is hermaphroditic and viviparous, the young worms at the time of birth being of large size and provided with practically all the organs of the adult except the sexual glands.

But few other species of nemerteans are as yet known to be viviparous, and most of these probably belong to the genus Prosorhochmus Keferstein, although several of them have been placed in other genera, and two of them, which have not been fully studied, belong to the Heteronemertea.

The distribution of the known viviparous forms is as follows:—

Prosorhochmus claparedi Keferstein. Mediterranean Sea, northern coast of France and England, and possibly the Black Sea.

Prosorhochmus korotneffi Bürger. Mediterranean Sea.

Borlasia vivipara Uljanin = *Monopora vivipara* Salensky. Black Sea. Probably belongs to Prosorhochmus.

Borlasia maslovskyi Czerniavsky. Black Sea.

Tetrastemma obscurum Max Schulze. Baltic Sea.

Tetrastemma lacustre Du Plessis = *Stichostemma lacustre*. Lake of Geneva.

Lineus viviparus Isler. Juan Fernandez. According to the collector, Dr. Plate, the young are born alive.

Lineus bilineatus McIntosh. Northern coasts of Europe, Mediterranean, Madeira. Chaupius ('86) describes a specimen which contained embryos, although other observations indicate that the species usually deposits its eggs.

Besides these forms, which are supposed to be strictly viviparous, several other species may have the eggs fertilized while within the body of the parent. This is the case in Carcinonemertes, in certain species of the fresh-water Stichostemma, and in *Geonemertes australiensis.*

In Carcinonemertes and some species of Stichostemma the egg may proceed in its development as far as the early stages of cleavage before being deposited. Indeed, in *Carcinonemertes carcinophila*, although most of the eggs of an individual are deposited immediately after fertilization and before cleavage, yet a small proportion of them may be retained in the body until the later stages of cleavage or even until the formation of free-swimming embryos (Coe, :**02**). In these forms, then, we find a striking intergradation between the strictly oviparous species and the few forms which are known to be regularly viviparous.

It seems conceivable, therefore, that *Geonemertes agricola*, which may be considered as normally viviparous, may under certain circumstances actually discharge its eggs while they are still in the early stages of development or even before cleavage, and that such eggs, deposited either in damp earth or in sea water, are fully capable of complete development.

Copulation.— In a normally viviparous animal in which the eggs do not develop parthenogenetically, some form of copulation is to be supposed. Nevertheless, Child (:**01**, p. 998) finds in Stichostemma that both kinds of sexual products mature in the same gonad at the same time and are discharged together; hence he believes that self fertilization usually occurs. Among the viviparous nemerteans several species have been observed in the act of pairing, an act which from the nature of the worm, with its hundreds of pairs of sexual openings along the sides of the body, must of necessity be a very simple process.

In Carcinonemertes a number of writers have observed the male and female worms to place their bodies side by side, either in an outstretched condition or somewhat folded, and then to secrete a large amount of mucus which encloses the bodies of both worms in a common mass of secretion. The eggs are then deposited from both sides of the body of the female and are fertilized by the sperm discharged simultaneously by the male. Sometimes several of each sex, sometimes a single male and two or more females, or, more often, a single male and a single female participate in this act. If it happen that a portion of the eggs in any of the ovaries are retained within the body of the female, such eggs are fertilized by spermatozoa which enter the openings into the ovaries.

In Stichostemma the process is very similar, although the eggs are often retained in the body of the female for some time after fertilization, and may be deposited when no male is in the vicinity. Several species of the genus are hermaphroditic and protandric (Montgomery, '95; Child, :01), and in some cases it is possible, or even probable, that self fertilization may occur (Child, :01). Du Plessis ('93) finds that in *S. lacustre* the males are smaller and much less numerous than the females, so that a single male may fertilize the eggs of several females. This is also the case in *Geonemertes australiensis* (Dendy, '93) and in the purely male form of *G. agricola.*

In *Geonemertes australiensis*, Dendy describes the male as lying upon the back of the female while discharging his spermatozoa, which then enter the ovaries of the female through the preformed oviducts and fertilize the mature ova contained therein. The spermatozoa have been seen in ovaries containing mature ova. In this species only a portion of the ova mature at one time, so that several clusters of eggs may be laid at intervals of a number of days. These are imbedded in an elongated mass of transparent jelly and deposited beneath damp moss, or under bark or stones. Although the eggs are very large, measuring 0.6 mm. in diameter, yet the process of their deposition does not cause serious rupture in the body walls of the mother.

Geonemertes agricola is often found with two or more individuals in contact, and when several specimens are kept in the same jar the bodies of all are sometimes stretched out side by side or somewhat folded, but in close contact. In this position the spermatozoa could readily pass from the body of one individual to that of another containing mature ova.

Other species of nemerteans have often been observed, particularly in the breeding season, to collect in clusters. The writer has described a case (: 01, p. 74) in which about 50 sexually mature individuals of *Micrura alaskensis*, some of which were 300 mm. in length, were coiled and twisted together in a single mass. This exaggerated gregarious instinct is doubtless associated with the reproductive processes.

That the deposition of genital products by one sex often excites the other sex to a corresponding act is attested by the observations of C. B. Wilson (: 00, p. 128), who noticed that when several sexually mature worms of both sexes are placed together in an aquarium the deposition of ova by one individual is often accompanied by the discharge of spermatozoa by another, even though the burrows of the two worms may be separated by a considerable space. These observations certainly indicate, as Wilson asserts, the existence of some sort of delicate sexual sense among the nemerteans.

DEVELOPMENT.

So far as is at present known the eggs and spermatozoa mature in the late spring and early summer, the fully developed young worms being discharged from the body in midsummer. The period of sexual maturity, however, as stated above, may possibly continue later in the year, although no observations have been made in the fall months. The exact time required for the completion of the developmental processes has not been determined because there is considerable variation in the time at which the eggs reach maturity in different individuals. There is little doubt, however, that a period of several weeks elapses between the time of fertilization of the eggs and the appearance of the young worms outside the body of the parent. In *Geonemertes australiensis*, the eggs of which are deposited immediately after fertilization, a period of several weeks is required to complete the development of the embryo. On the 26th day after the ova had been deposited, Dendy ('93, p. 130) found a portion of the embryos nearly ready to crawl about, although others were as yet within the egg membranes. At least a month seems to be required for the development from the time of fertilization to the arrival at the elongated, worm-like form provided with ocelli.

The details of the process of fertilization have not been observed, nor has the cleavage of the egg been followed through all its stages. The development of the principal organs of the body of the embryo, however, can be followed in this species as in few other Hoplonemertea.

The body of the young worm proceeds directly from the fertilized egg without any distinct metamorphosis, although it is not quite certain that the ciliated covering of the young embryo is actually converted into the ciliated integument of the adult worm. The possibility remains that the very thin and inconspicuous larval covering is sloughed off, either bodily or as individual cells, during the early stages of embryonic life, and that the integument of the adult takes its place.

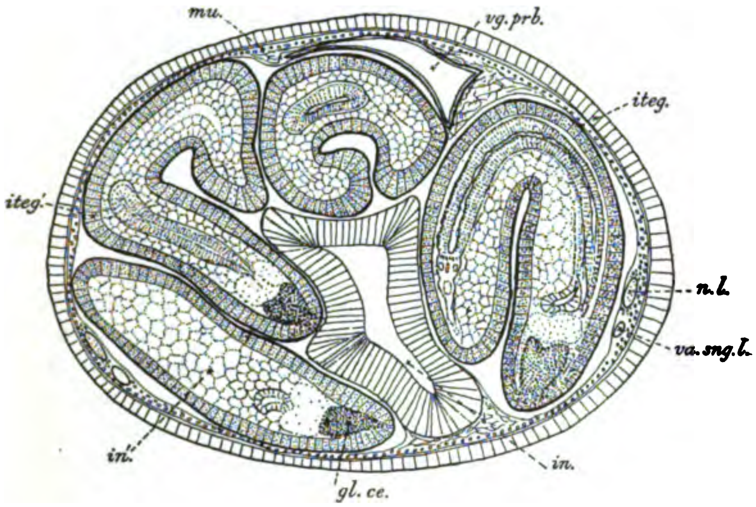

FIG. C.—Transverse section of body of worm with nearly mature embryos, showing the large size of the 4 embryos cut in the section, and their consequent encroachment on the tissues of the parent. They are closely crowded in the body, the anterior end of embryo commonly lying toward the ventral side of body of parent; *in* and *in'*., intestine; *vg. prb.*, cavity of proboscis sheath; *n. l.*, lateral nerve; *va. sng. l.*, lateral blood vessel; *iteg.* and *iteg'.*, integument; *gl. ce.*, cephalic glands of embryo. × 70.

The developing embryos increase rapidly in size and become elongated until their length may be twice as great as the diameter of the body in which they develop. They thereby cause great distension of the body walls of the parent. They encroach to so great an extent on the tissues of the body as to interfere greatly with the performance of its normal functions, reducing the lumen the lateral border of the brain lobe. This canal represents what is later to become the glandular portion of the sense organ, although it is at first surrounded by ganglion cells (pl. 24, fig. 12). The body of the sense organ likewise extends back along the lateral face of the brain.

The primitive position of the sense organ is thus seen to be immediately anterior and lateral to the anterior end of the brain, so that a transverse section through this region of the brain passes through the posterior part of the sense organ (pl. 24, fig. 11). This remains the permanent position in some species of the genus, as in *G. australiensis*, where the glandular canal extends posteriorly beside and even behind the brain. In *G. agricola*, however, the body of the sense organ remains of small size and comes to lie at some little distance in front of the anterior end of the brain. The opening of the ciliated tube on the exterior of the head in the adult is placed much farther forward relatively to the brain, and the tube itself is much more slender than is the case in the embryo.

The change in the relation of these organs is accomplished by the growth of the connective, muscular, and glandular tissues in front of the brain, so that this organ, which lies so near the anterior end of the body in the embryo, is pushed far back from the tip of the snout in the adult worm. An elongation occurs also in the rhynchodaeum and in the cephalic glands. It is of particular interest to note that in many species of Hoplonemertea this primitive position of the sense organ corresponds so closely with the final position in the adult.

Cephalic glands.— Early in the development of the embryo certain ectodermic cells at the anterior end of the body sink inward beneath the integument and by increase in both size and number give rise to the cephalic glands. The cells are at first of small size but later become distended with an enormous amount of deeply staining secretion, so that they are very conspicuous from an early period in all embryos (pl. 23, figs. 5, 6; pl. 24, figs. 10, 12, 13; pl. 25, fig. 19). They gradually migrate posteriorly, some of them passing behind the brain lobes, but remain connected with each other anteriorly and continue to discharge their secretions at the tip of the snout. A tubular invagination of the superficial epithelium on the snout forms a deep pit, into which the glands then pour their secretions. This pit grows back as far as the brain lobes and becomes lined with a sensory epithelium to form the highly specialized frontal organ of the adult (fig. A, p. 540).

Alimentary canal.— When the body of the young embryo begins to elongate, the blastopore and, to all appearances, the whole lumen of the primitive alimentary canal become obliterated. The whole interior of the body is then occupied by a mass of large vacuolated endodermic cells, this mass filling practically the entire space enclosed by the body walls as far forward as the brain (pl. 24, fig. 12).

In most individuals no lumen whatever is to be found within this mass of cells until a comparatively late period in the embryonic development, when the body has become decidedly worm-like in shape. A splitting then occurs which gives rise to a conspicuous lumen passing through the midst of the cell mass. This lumen forms the cavity of the intestine proper and the intestinal caecum of the adult. It extends throughout the length of the endodermic mass, from near the brain region to the posterior end of the body. Whether this splitting takes place along a line corresponding to the earlier position of the primitive alimentary canal is uncertain, this canal having been so completely obliterated at a much earlier period.

In the meantime an invagination at the anterior end of the embryo gives rise to the rhynchodaeum. This invagination grows posteriorly as a rather narrow canal nearly to the brain, where it swells out into a conspicuous chamber (pl. 24, figs. 10, 13). From this chamber two limbs grow out, of which one passes directly backward between the brain lobes and dorsal to the commissure and continues posteriorly to form the lining of the proboscis (pl. 24, figs. 11, 13). The other limb bends sharply ventrally and passes on the ventral side of the brain commissure as a narrow tube, the esophagus, which enlarges immediately behind the brain into an oval chamber of considerable size, the stomach.

Both rhynchodaeum and esophagus are at this time lined with rather small columnar cells, while the stomach has very large, highly columnar cells, a portion of which are covered with long and conspicuous cilia, while others are converted into gland cells (pl. 24, figs. 12, 13).

The stomach remains for some time as an oval chamber imbedded in the anterior portion of the endodermic mass immedi-

At this time the space between the dissepiments is filled with a solid mass of cells. The cells then split apart to form a lumen continuous with that of the main intestinal canal. The cells of the pouch are then rearranged into a single layer on each side of the lumen, each cell assuming a more columnar shape. In the elongation of the cell to its final columnar form the cytoplasm and vacuoles are rearranged in the cell, and the nucleus is pushed down toward the base, that is, toward the side of the cell farthest from the lumen.

The endodermic cells of the early embryo are of large size and comparatively few in number. Each cell is thickly crowded with yolk spheres, most of which are rapidly absorbed, although a few remain until the embryo is nearly mature. With the absorption of the yolk occurs a marked vacuolation of the cytoplasm (pl. 24, figs. 12, 16), which increases in prominence up to the time of the formation of the definite epithelium, when the cell changes its shape as above described. With the assumption of the ultimate columnar form of the cell, the vacuoles disappear, and are replaced by the granules of the secretion so characteristic of the intestinal cells of the adult. With the growth of the body the central lumen of the intestine becomes comparatively narrower, and the intestinal lobes very much deeper; this applies with equal force to the intestinal caecum, which has similar paired diverticula.

The anus and rectum are formed, as in other species, by mutual ingrowth from the ectoderm at the posterior end of the body and outgrowth of the posterior end of the intestinal canal. The alimentary canal thereby assumes the form of a continuous tube open at both ends of the body, with intestinal diverticula as in the adult. The lining of the rhynchodaeum, esophagus, stomach, pylorus, and anus is thus derived from the ectoderm, while the lining of the intestine proper and intestinal caecum is endodermic in origin, as stated above. This appears to be true not only for the Hoplonemertea in general, where a direct type of development is the rule, but also for the Heteronemertea, which pass through a complicated metamorphosis.

Proboscis.— The ectodermic invagination forming the rhynchodaeum widens out into a conspicuous chamber immediately in front of the brain, from which the esophagus grows back beneath the brain commissure as described above. A similar posterior growth from this chamber passes between the brain lobes on the dorsal side of the commissure. This outgrowth forms the lining of the proboscis, which is consequently of ectodermic origin. This ectoderm grows backward as a solid mass of cells, which soon arrange themselves into a narrow tube lined with cuboidal or low columnar cells. Its growth posteriorly is accompanied by a multiplication and crowding together of the adjacent mesodermic cells, which later form the muscular walls of the proboscis.

The tube with its cap of unarranged ectodermic cells grows backward toward the posterior end of the body in the median line, dorsal to the mass of endoderm cells and immediately internal to the body walls. A section through the body at the point just reached by the end of the advancing proboscis (pl. 25, fig. 17) shows a solid mass of cells of which the central ones are probably ectodermic and the lateral ones mesodermic in origin.

As the growth continues to the posterior end of the body the ectodermic lining of the tube of the proboscis remains closely invested with mesodermic cells, which form the muscular and connective-tissue walls.

The mesoderm immediately surrounding the proboscis becomes separated from the adjacent mesoderm, the cleft forming the rhynchocoel. The adjacent mesoderm forms the proboscis sheath, which for a long time remains as a single layer of delicate fibers (pl. 25, fig. 18). It later becomes thickened and its musculature is arranged in definite layers as in the adult. In Carcinonemertes (Coe, :02) the separation of the proboscis from the proboscis sheath takes place only as far back as the anterior end of the posterior chamber, the walls of this chamber remaining permanently connected with the walls of the sheath.

The development of the armature of the proboscis proceeds very much as in Prosorhochmus as described by Bürger ('95, p. 482). At a definite point in the posterior third of the proboscis the muscular and connective tissues increase to form a thick transverse septum, which marks off the proboscis cavity into an anterior and a posterior chamber. These two chambers remain connected by a comparatively narrow tube, which is at first lined with a single layer of regularly arranged columnar cells (pl. 25, fig. 20). On one side of this narrow tube a small evagination of the columnar epithelial cells forms a short pouch, which is without any lumen, consisting of an almost solid mass of columnar epithelium. These cells then become arranged to form a narrow cylinder, and pour out a solid granular secretion which immediately hardens to form the basis of the central stylet.

The cells of this cylindrical mass are at first without any very definite arrangement, so that the first indication of the basis is a solid rod of secretion without definite shape. Gradually, however, the secreting cells (pl. 25, fig. 20–25) assume very definite positions and are arranged around a lumen of characteristic shape, thus making a mold in which the secretions harden to form a stylet basis of exactly the same proportions. The mold is at first very narrow, so that primarily the basis is slender, cylindrical, and very small.

The great diversity in the shape of the basis in different species of Hoplonemertea is thus dependent upon the arrangement of the cells forming the mold into which the secretion that forms the basis is poured.

The basis increases in size with the accumulation of secretion and gradually acquires the definite form characteristic of the adult. Even in a nearly mature embryo, however, the basis is still much more slender and of vastly smaller size than in the adult. A comparison of the diameter of the basis of an adult worm with that of an embryo still in the body, but nearly mature, is represented in figure D, the larger circle representing the outline of the basis in the proboscis of the adult, and the much smaller circle in the center of the large one, a similar outline in the embryo. The relative diameters are about as 1 to 10, thus corresponding with a comparative cross section of 1 to 100. The basis is, however, much more slender in the embryo than in the adult, the relative lengths being about as 1 to 4 or 5. The actual bulk of the basis in the adult is therefore not far from four or five hundred times that of the corresponding part in the mature embryo.

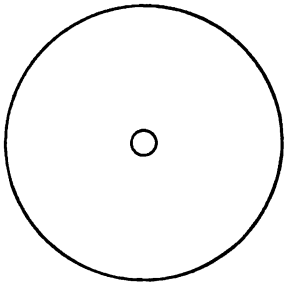

FIG. D.—Diagram showing comparative size of cross sections of basis of central stylet in the adult worm (outer circle), and in a nearly mature embryo (inner circle); both drawn to the same scale. × 567.

The cylindrical outgrowth of cells which secrete the basis takes place from the wall of a conspicuous chamber (pl. 25, fig. 20) in the thick septum described above. The cylinder of cells lies oblique to the longitudinal axis of the proboscis for a short time, but soon comes to lie symmetrically nearly in the center of the proboscis. At the same time the canal connecting the anterior and posterior chambers of the proboscis is greatly reduced in size, and the chamber behind the septum is constricted by an ingrowth of the proboscis walls into a middle and a posterior chamber. The chamber from which the outgrowth takes place is likewise reduced in size, so that it surrounds the central stylet rather closely (pl. 25, fig. 21). It leads forward to the anterior chamber of the proboscis, into which it opens by a comparatively narrow tube.

The opening is almost obliterated, or at least hidden from view, by an enormous growth of deeply staining gland cells (pl. 25, figs. 20, 21), which form a broad and thick disk on the anterior margin of the septum. The glands pour their secretions into the anterior proboscis chamber. Similar glands occur in nearly all Hoplonemertea, sometimes remaining as a disk at the posterior end of the anterior chamber, but more often sinking deeper into the tissues of the septum, and assuming the form of a wreath which surrounds the stylet apparatus, but situated in the peripheral portions of the septum.

These glands have been commonly looked upon as themselves forming the secretion out of which the basis is composed, although, as shown above, that function belongs to other cells. Their secretion is poured either into the anterior chamber or into the canal passing through the septum, the basis being composed entirely of the secretions of the cylinder of cells described above. In transverse section (pl. 25, figs. 22, 23) these cells are seen to be symmetrically placed around the circular lumen filled by the basis. The nuclei likewise form a nearly perfect circle, all being situated at an equal distance from the lumen. The cell membranes are often inconspicuous, although a distinct line of granules of secretion can be seen in the interior of the cell, extending from near the nucleus outward to the free border of the cell (pl. 25, figs. 22, 23).

The definite origin of the central stylet itself has not been determined with certainty. Bürger ('95, p. 482) finds in Prosorhochmus that the accessory stylet pouches are each composed of a single cell only, the stylets themselves being formed as a secretion in this cell. After its formation in this manner one of the stylets passes through the duct leading from the pouch to the anterior proboscis chamber and is thence transferred to the apex of the basis, which has already been formed in the manner above described. The central stylet is thus supposed to be replaced from time to time by one of the accessory stylets.

Although it cannot be stated positively, a study of the developing stylet in Geonemertes indicates strongly that the central stylet is actually formed *in situ* on the apex of the basis. In Carcinonemertes, in which no accessory stylet pouches or stylets are present, the central stylet must of necessity be formed at or near its ultimate position at the apex of the basis. This would support Montgomery's view that at least in certain forms the central stylet originates independently of the accessory stylet pouches.

HABITS.

The species is found in abundance at several places on the Bermuda Islands, but so far as known, occurs only along the shores of mangrove swamps and on the adjacent hillsides. In the summer it has been found only in the moist soil near high-water mark, although it probably also occurs higher up on the hillsides, where it has been found in the spring months. In the summer these hillsides become very dry at the surface so that the nemerteans probably follow the burrows made by the earthworms deeper into the soil, where moisture is more abundant.

Near high-water mark on the edge of the mangrove swamps the soil consists mainly of black mud succeeded by a dark or reddish loam farther up the banks. Under stones, sticks, and rubbish of various sorts in such localities occurs an abundance of earthworms of various species, of which some are indigenous and others imported accidentally. Associated with these earthworms are nematodes and sometimes insects, as well as the species of nemertean which forms the subject of this investigation.

The nemertean is easily distinguished by its pale gray, whitish, or orange color, and by the large whitish proboscis which it everts when irritated. It occurs not only above high-water mark but also for some distance along a zone which is covered for a short time each day with sea water. This is also true for one or more species of earthworms. Individuals found between tides are as a rule of smaller size than those living in the soil which is a little above the reach of the tide, but in earth which is nearly saturated with salt water.

The worms do not burrow in the soil, but lie beneath stones and other substances that will protect them from the rays of the sun and also, it is to be supposed, from their enemies. They are often found at some distance beneath the surface of the soil, having followed the burrows made by earthworms.

It is of interest to note that another species of nemertean, belonging to the genus Lineus, occurs in some of the same localities and is found from the zone of half tide nearly up to high-water mark. This Lineus often occurs under the same stone with specimens of Geonemertes, and like the latter will live a long time in earth moistened with sea water.

Willemoes-Suhm (**'74**, p. 411) observed that the land nemerteans are not injured by pouring fresh water over the earth in which they are living, but that immersion in fresh water kills them in a few hours.

Numerous individuals were subjected to a series of experiments by the writer, and demonstrated their extreme hardiness by surviving under the most rigorous conditions. A dozen worms placed in a jar of sea water lived for several weeks without food or change of water. Unless disturbed they spent their whole time, at least in daylight, above the surface of the water, clinging in a horizontal position against the sides of the vessel in which they were contained. Several specimens were usually stretched out side by side in close contact. In damp earth the worms were as active at the end of four weeks as at the beginning. In such earth they collect in groups in small cavities which they find and which they line with their mucous secretions. The earth can even become comparatively dry without injury to the worm. Fresh water can be added in considerable amount to the soil or to the salt water in which the worms are living with no apparent unfavorable results, although the worms will not live in fresh water alone.

The origin of the land nemerteans has been the cause of a considerable amount of speculation, most writers holding that they must have come from marine forms. Montgomery, however, in a very suggestive paper (**'95a**, p. 483) argues that most, if not all land nemerteans probably have descended from fresh-water forms.

The habitat of the Bermudan species as described above, however, and the presence of the form on islands where little or no fresh water occurs either in streams or pools other than those formed immediately after a shower, practically proves the origin of at least one form directly from a marine ancestor.

It is not known whether the species is indigenous to Bermuda, for it is possible that it may have been accidentally introduced, in company with earthworms, with plants from some other part of the world. It is, however, quite distinct from any of the other known species of the genus, and is widely distributed on these islands. The fact that it lives below high-water mark as well as above sea level would indicate that it is indigenous if not peculiar to the Bermudas, for few if any plants living in the zone inhabited by the nemerteans have been introduced by man.

The species occurs abundantly on the borders of the mangrove swamps at Hungry Bay and at Bailey's Bay, and has been found at Walsingham Bay, on the shores of Castle Harbor, near the "Causeway," at Hamilton Harbor, and in other localities.

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EXPLANATION OF PLATES.

ABBREVIATIONS.

Except when otherwise indicated, a prime (′) mark following an abbreviation indicates that the organ in question belongs to an embryo.

a. Anterior chamber of proboscis.
can. Canal from middle to anterior chamber of proboscis.
can. cil. Ciliated canal of cerebral sense organ.
cb. Brain.
cl. n. Nerve cell.
dt. Duct from accessory stylet pouch.
emb. Embryo.
foll. Follicular epithelium; follicle.
gas. Stomach.
gl. Gland cell.
gl. ce. Cephalic glands.
in. Intestine, or endoderm of embryo.
in. coe. Caecum of intestine.
iteg. Integument.
m. Middle chamber of proboscis.
mb. ba. Basement membrane.
mu. Muscular layers.
mu. crc. Circular muscles.
mu. lg. Longitudinal muscles.
nl. Nucleus.
n. l. Lateral nerve.
nll. Nucleolus.
oes. Esophagus.
of. pyl. Opening of pylorus into intestine.
o. sns. Cerebral sense organ.
ov. Ovum.
ovy. Ovary.
p. Posterior chamber of proboscis.
prb. Proboscis.
pyl. Pylorus.
rhnc. Rhynchocoel.
rhnd. Rhynchodaeum.
sp'go. Spermatogonia.
sp'go′. Spermatocytes.
spy. Spermary.
sp'zo. Spermatozoa.
va. sng. Blood vessel.
vg. prb. Proboscis sheath.

PLATE 23.

Geonemertes agricola.

Fig. 1. Small, but sexually mature individual of the pale colored variety. × 8. Bailey's Bay.

Fig. 2. Individual of the orange colored variety with brownish intestinal lobes. This specimen was crowded with nearly mature embryos, and had in addition small spermaries with well formed spermatogonia and spermatozoa as well as small ova in separate gonads. Compare figures 6, 7, 8, and 9. × 5. Hungry Bay.

Fig. 3. Central stylet and basis, showing lobes on head of stylet. × 300.

Fig. 4. Two of the five accessory stylets with lobed heads from one of the two lateral pouches. × 300.

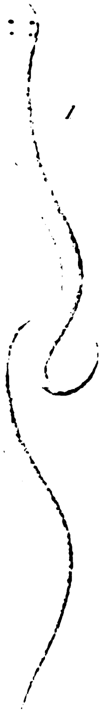
Fig. 5. Transverse section of body of an individual with nearly mature embryos, both of those shown having the head directed toward the ventral side of the body. The embryos have encroached upon the tissues of the body to such an extent as greatly to reduce the size of alimentary canal and other organs. × 30.

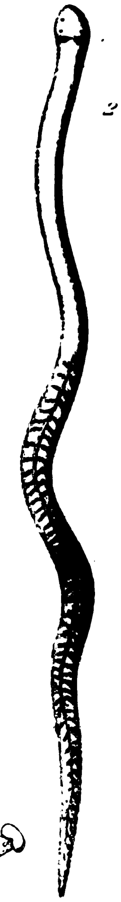
Fig. 6. Portion of parasagittal section of body of worm, anterior to the left, containing large embryos as well as small pouches of immature eggs and spermatozoa. × 30. Compare figures 7, 8, and 9.

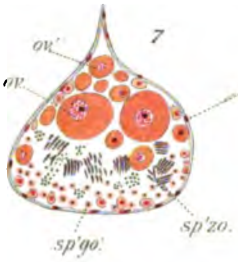
Fig. 7. Immature genital gland from same individual as that of figure 6, showing the development of both ova and spermatozoa in the same gonad. × 150.

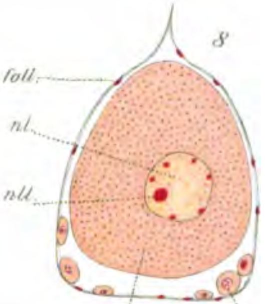
Fig. 8. Genital gland (ovary) from same individual as in figures 6 and 7, showing the development of a single ovum in the gonad. × 150.

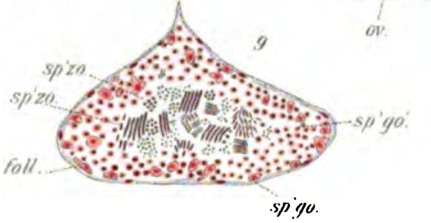
Fig. 9. Genital gland (spermary) with developing spermatozoa. From same individual as in figures 6, 7, and 8. × 150.

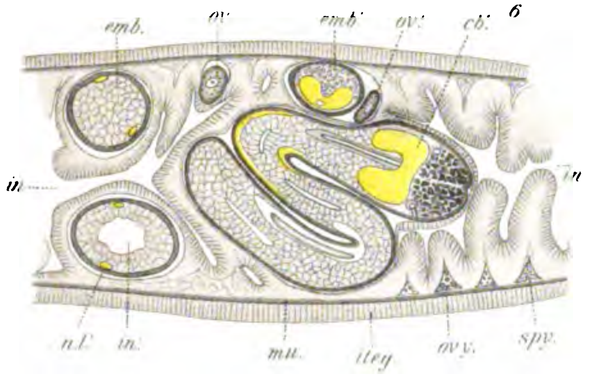


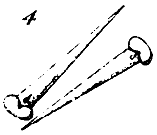


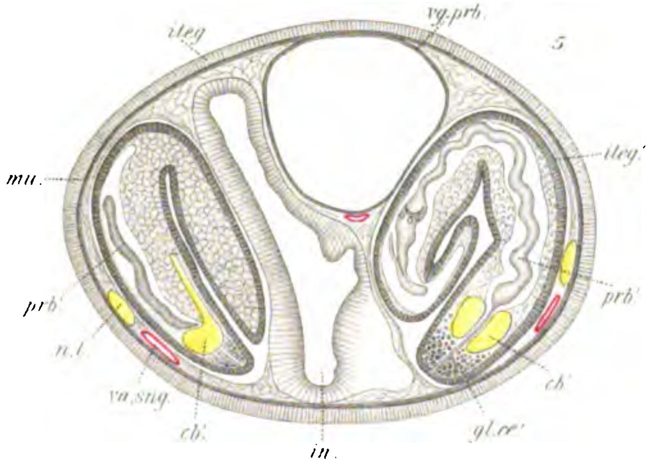


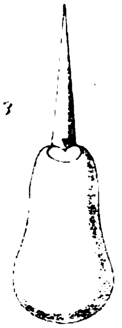












W. R. C. del.

B. Meisel lith. Boston

PLATE 24.

Geonemertes agricola.

Fig. 10. Frontal section of young embryo, showing the solid mass of endodermic cells (*in.'*) of the future intestine, the very large brain lobes (*cb.*), the well developed cephalic glands (*gl. ce.*), the rhynchodaeum leading into an oval chamber in front of brain, and esophagus passing into stomach (*gas.*). × 237.

Fig. 11. Transverse section through brain region of young embryo of about the same age as that shown in figure 10. The large brain lobes (*cb*) are united to each other by a broad ventral commissure, above which is the large proboscis (*prb.*) and below which is the narrow esophagus (*oes.*) × 237.

Fig. 12. Frontal section of anterior portion of body of late embryo showing large, vacuolated endodermic cells (*in'.*), which later form the intestinal caecum. The stomach (*gas.*) is situated directly behind the brain lobes. Cerebral sense organ (*o. sns.*) well developed, and broad ciliated canal (*can. cil.*) opening laterally. × 237.

Fig. 13. Sagittal section of anterior portion of nearly mature embryo. Rhynchodaeum (*rhnd.*) leads into broad chamber in front of brain (*cb.*), from which chamber the esophagus (*oes.*) passes to stomach (*gas.*), and the latter through the long pylorus (*pyl.*) leads into intestine (*in.*) through a narrow opening (*of. pyl.*) ; *in. coe.*, cavity of intestinal caecum, which later grows forward through solid mass of endoderm cells (*in'.*). × 237.

Fig. 14. Parasagittal section of portion of intestinal tract of fully mature embryo, showing the arrangement of the vacuolated endodermic cells between fibrous dissepiments, thus forming the metameric intestinal lobes. × 237.

Fig. 15. Transverse section through intestinal lobe of mature embryo. × 237.

Fig. 16. Portion of frontal section of integument and lateral nerve (*n. l.*) of mature embryo, showing relation of glandular (*gl.*) and ciliated cells of integument, the nerve cells (*cl. n.*) bordering fibrous core of nerve, and vacuolated cells of endoderm (*in.*). × 530.

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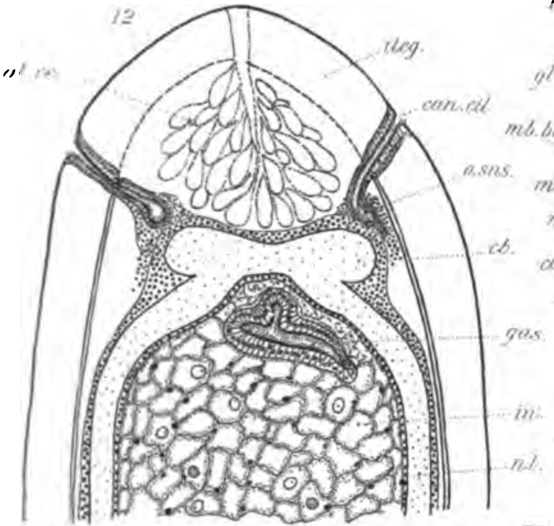

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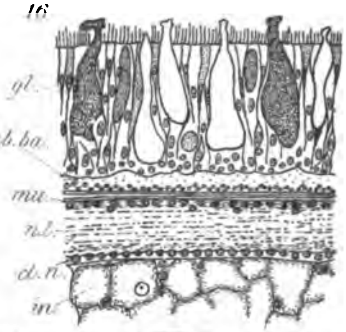

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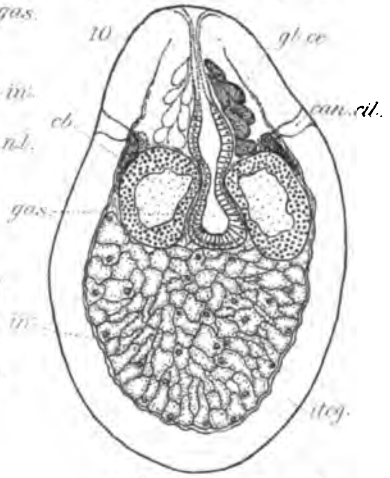

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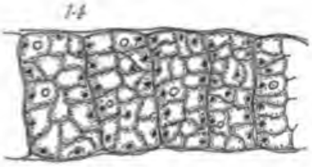

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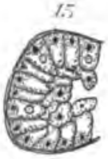

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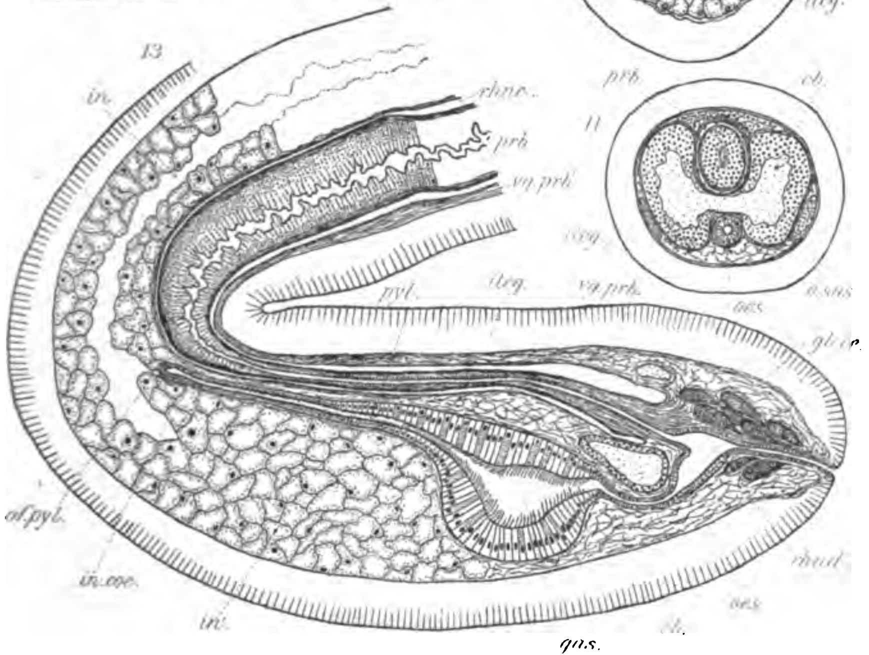

W R C del.

B Meisel lith Boston

PLATE 25.

Geonemertes agricola.

Fig. 17. Transverse section of body of early embryo, showing the solid mass of endodermic cells (*in'.*), the lateral nerve (*n. l.*), and the group of ectodermic and mesodermic cells (*prb'.*) which later form the proboscis and proboscis sheath. × 237.

Fig. 18. Transverse section of body of late embryo, showing vacuolated endodermic cells surrounding cavity of intestine (*in.*), and the well developed proboscis (*prb.*) in proboscis sheath. × 237.

Fig. 19. Nearly frontal section of anterior portion of body of late embryo, showing rhynchodaeum (*rhnd.*) leading through narrow esophagus to stomach (*gas.*), the relations of brain (*cb.*) to lateral nerve (*n.l.*), and the highly developed cephalic glands (*gl. ce.*). × 237.

Fig. 20. Portion of longitudinal section of proboscis, showing the central stylet and basis formed from an outgrowth of the proboscis epithelium. × 530.

Fig. 21. A similar section in a somewhat later embryo, showing the two pouches of accessory stylets opening through duct (*dt.*) into anterior chamber. × 530.

Figs. 22 and 23. Transverse sections of basis of central stylet in mature embryo, showing relations of cells by which the basis is secreted. × 530.

Figs. 24 and 25. Longitudinal sections of basis of central stylet, showing outline of mold formed by the epithelial cells by which basis is secreted. × 530.

Fig. 26. Portion of transverse section of body of worm which contained mature embryos, showing one of the spermaries which develop at the same time. The efferent duct leads into, but not through, the integument (*iteg.*). Groups of spermatogonia (*sp'go.*), spermatocytes (*sp'go'.*), and spermatozoa (*sp'zo.*) in various stages of development occur. × 530.

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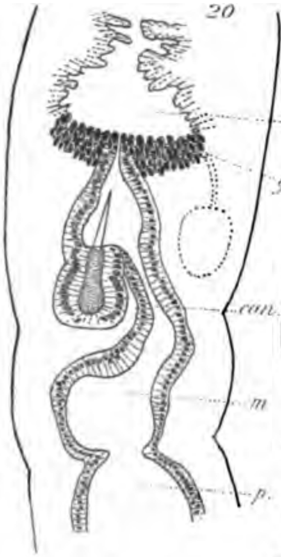

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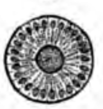

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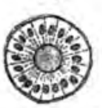

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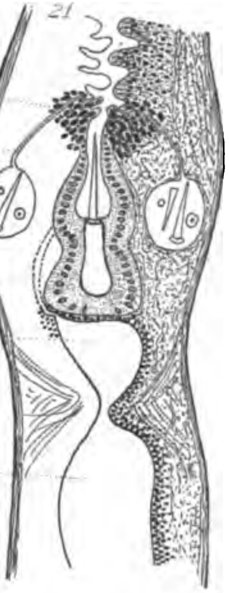

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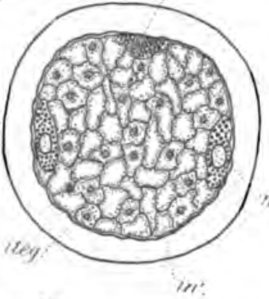

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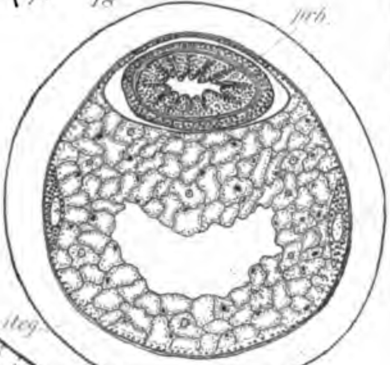

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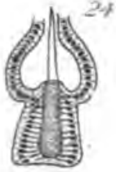

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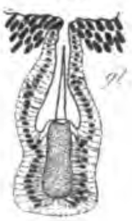

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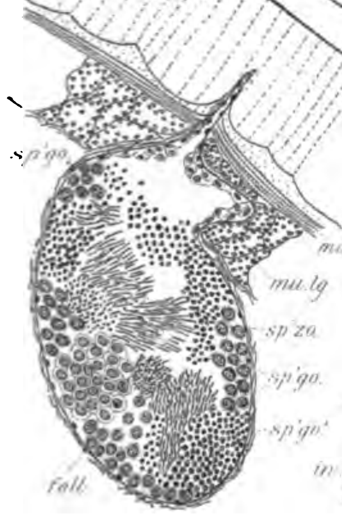

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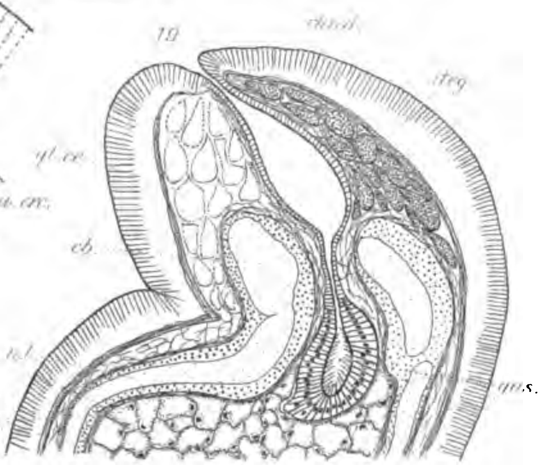

W. R. C. del.

B. Meisel, lith. Boston.

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59 (729.9)

CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL STATION
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With Four Maps.

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THE SHOAL-WATER DEPOSITS OF THE BERMUDA BANKS.*

BY HENRY B. BIGELOW.

Presented by E. L. Mark, December 14, 1904. Received October 19, 1904.

THE sea-bottom deposits described in the following pages were collected during the summers of 1903 and 1904 at the Bermuda Biological Station for Research, to whose Director, Professor E. L. Mark, the writer is indebted for many courtesies and much practical assistance. The collection comprises seventy-six samples, the most of them preserved in alcohol, dredged at sixty localities in the lagoons and sounds, and from the beaches, of the Bermuda Plateau, as well as the material taken in twelve dredge hauls made during a three-days' expedition to the Challenger Bank. No attempt was made to secure samples in the deeper waters on the sea faces of the banks.

The general topographic features of the Bermudas have been thoroughly studied by Rein ('81), Heilprin ('89), and Agassiz ('95), and I shall commence with a brief résumé of their accounts. The Bermuda Bank (Map 1, p. 560) is oval in outline, its longest axis, which lies northeast and southwest, being about thirty miles, and its breadth about fifteen; an area of some two hundred and seventy-five square miles. For the purposes of the present description I shall consider the thirty-fathom line as its limit, for at about that depth the abrupt slope to deeper oceanic waters commences. The land mass, which consists of a number of small islands, lies in a somewhat crescentic form on the southern side of the bank, where it forms an almost continuous barrier, but its entire area is not more than fifteen thousand acres (less than 24 square miles). Commencing at either extremity of the land mass and running thence around the northern side of the bank, at about the twelve-fathom line, some three miles inside the thirty-fathom line, is the so-called "boundary reef," or "ledge flat." This is perhaps three-fourths of a mile in breadth, awash in many places at low tide, and penetrated by several narrow "cuts," of which the most important are "Hogfish," on the southwest;

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* Contributions from the Bermuda Biological Station for Research, No. 5.

"Chub" and "Western Blue," on the west; "Mills Breaker" and the "Ship Channel," on the east. On the southeast, running about parallel with the land and at a distance of one to three miles, is a line of detached ledges. The great "lagoon," enclosed by the boundary reef, is of rather uniform depth, from five to ten fathoms, but is broken in several localities by great numbers of shoals and ledges, while the Islands themselves enclose several large sounds, which are in more or less free communication with the sea. The rise and fall of the spring tides at Ireland Island (Map 4), as given on the admiralty charts, is four feet, — only about eight inches more than the vertical height of the tidal wave. The inflow of water into the great lagoon takes place over the whole boundary reef, so that it forms no strong currents, except through the cuts. On the bank as a whole, with the exception of one or two inlets, — for instance the Flatts Inlet into Harrington Sound (Map 3), — the tidal currents are too slight to cause any important transference of materials. Bermuda lies nearly one hundred miles south of the southern margin of the Gulf Stream, and there is no general sweep of water across the bank, while the land crescent forms an effective barrier against any surface currents which might follow the prevailing southerly winds.

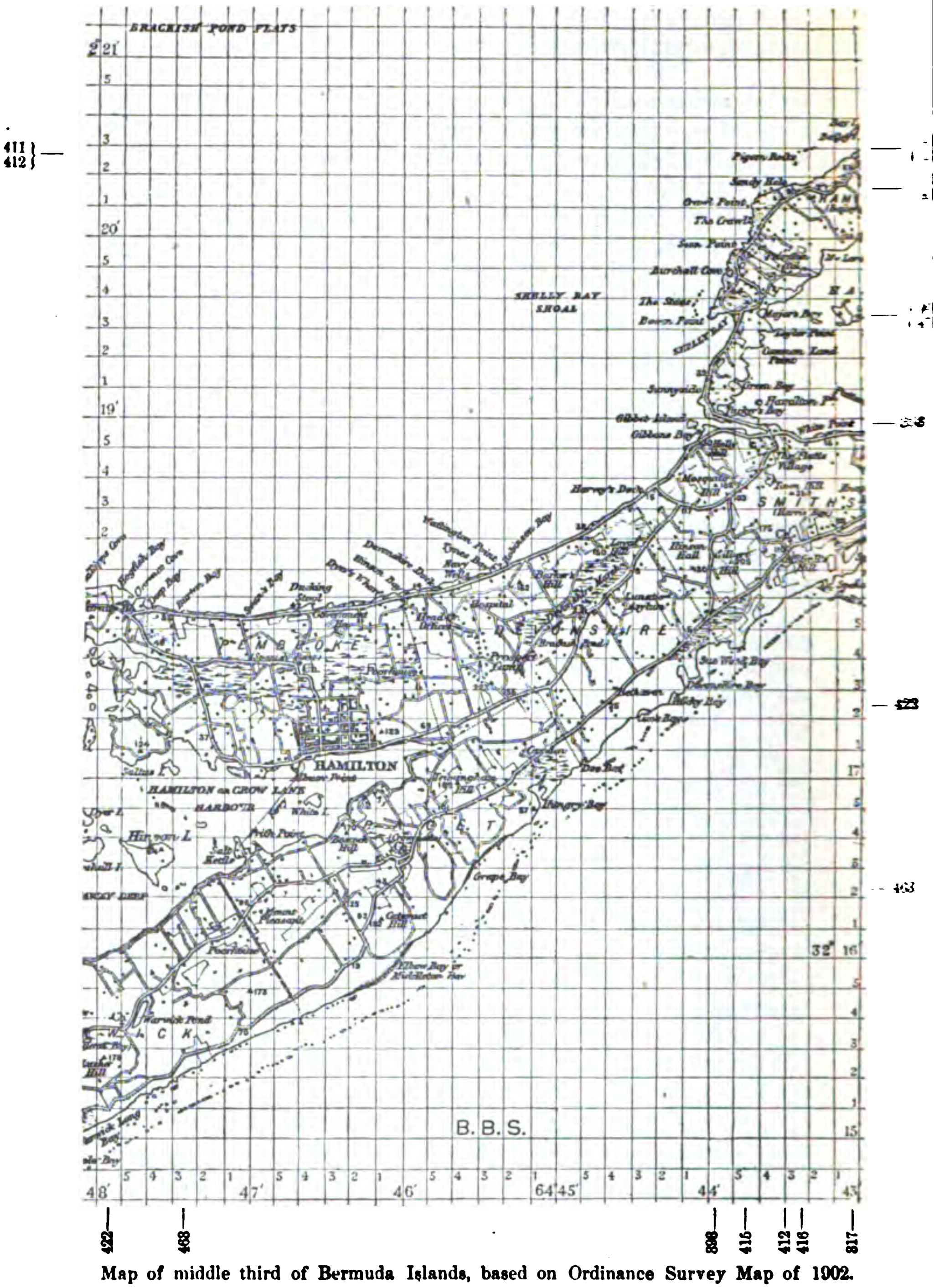
A good account of the probable geologic history of Bermuda — a gradual upbuilding of a volcanic cone by the accumulation of organic débris, followed by a subsequent subsidence — has been given by Agassiz ('95). No outcrop of volcanic rock has ever been found, but it is generally agreed that the core of the bank is of that nature, although buried under a thickness of limestone which is estimated by Agassiz as at least four hundred and fifty feet. The limestone of which the islands consist is of aeolian origin, being formed from wind-blown sand by a consolidation due to the action of water percolating through it, a process which is still going on in the dunes at Tucker's Town (Map 2). This aeolian rock is underlaid in places by the much harder beach rock, which is now being formed at Great Turtle Bay (Map 4), on the south shore. Whether there was ever any considerable elevation of the bank above the level of the sea, or whether the dunes and sandhills were formed near that level, as maintained by Agassiz, is of no great moment in this connection, but it is certain that at one time most of the surface of the bank was dry land and that it has subsequently subsided until only the narrow chain of islands remains above water. An outcrop of this ancient land remains in the "North Rocks." Agassiz has described the formation of the lagoons as resulting from the breaking down of the walls between natural depressions owing to denudation combined with the destructive action of the sea, and he has shown beyond question that the reefs and ledges are composed of aeolian limestones, being the remnants of bluffs or cliffs, undercut and demolished by the sea, a process now taking place actively on the south shore.

The most important point to be borne in mind in any study of the physiography of the Bermudas is that the ring-like outline of the reefs bears no relation whatever to an atoll; and that Bermuda is not in any true sense a coral island, although coral grows there in some profusion. There is no coral reef on the plateau; and we have no reason to suppose that Bermuda ever showed any more of the characters of an atoll than it does to-day. Coral fragments are rather rare in the aeolian rock, though other organic remains are recognizable in abundance. Mr. Agassiz says ('95, p. 228) that he never saw a piece of coral in Bermuda above high-water mark where its presence could not be explained by storm winds or waves. The living corals have added very little to the vertical height of the reefs, forming merely a thin covering, which, with the encrusting masses of serpula tubes, protects the limestone of the ledges against the attacks of the surf.

Although the general features of the Bermudas, both geographic and geologic, are so well known, but little attention has been paid to the bottom deposits. Almost the whole information which we possess on this subject is contained in the brief accounts of the Challenger expedition and of Mr. Agassiz's explorations.

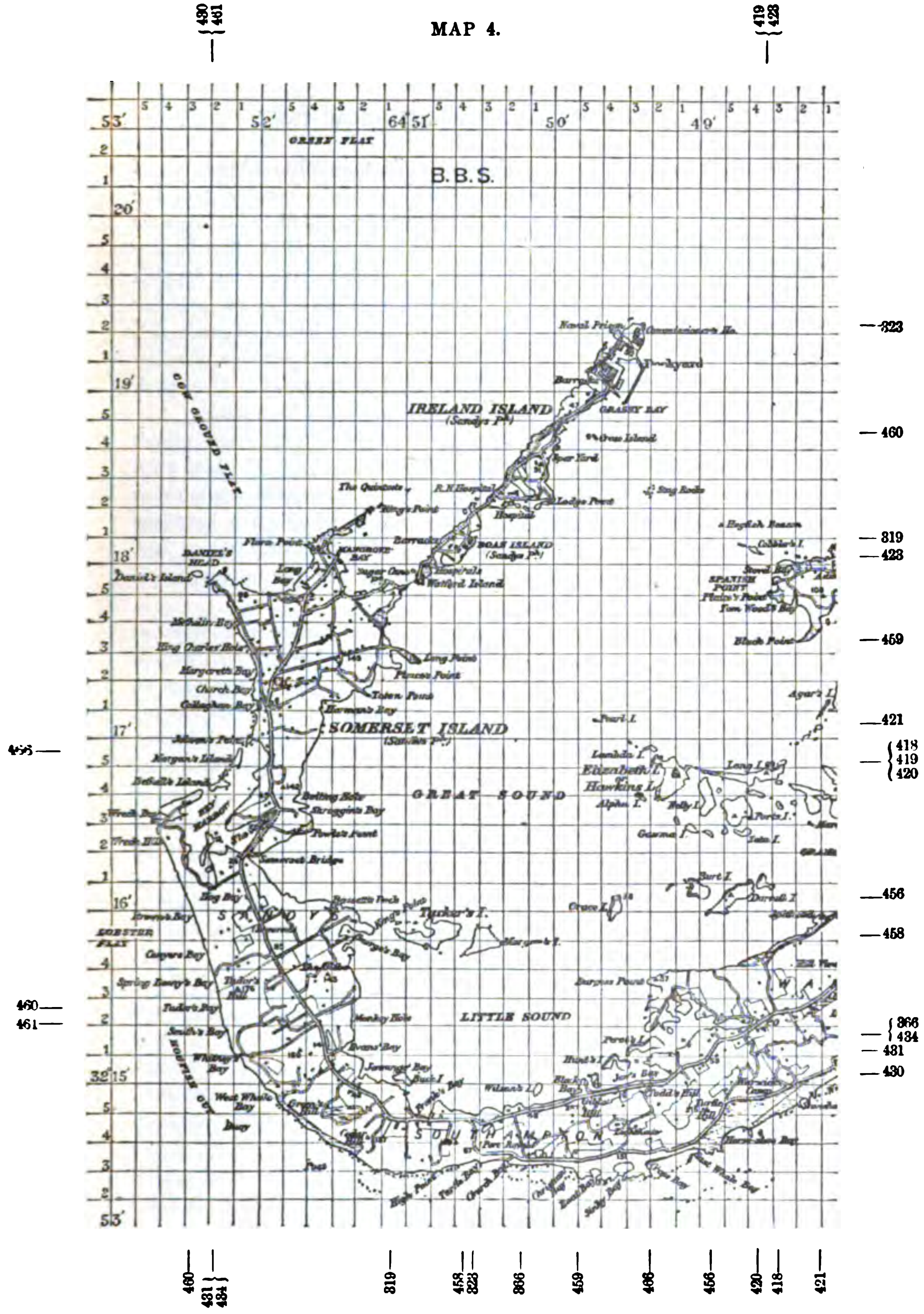
Murray and Reynard ('91, p. 48) analyze four samples of coral sand and mud from as many localities inside the reef, and find that calcic carbonate composes the following proportion of the deposits. No. 1, from the northern half of Murray Anchorage, in nine and a half fathoms, 95.43 per cent; No 2, near the Ship Channel, in five fathoms, 91.09 per cent; No. 3, on the Cow Ground Flat, 90.18 per cent; and No. 4, in Murray Anchorage, in six fathoms, 86.77 per cent. In three of the samples calcareous algae and their broken-down parts composed over 50 per cent of the mass, and Foraminifera, 10 to 30 per cent, the balance consisting of serpuline, gasteropod, and lamellibranch fragments, corals and millepores, ostracods, and plates and spines of echinoderms; 1 to 2 per cent was of mineral origin, fine particles of quartz and mica; and 2 to 10 per cent was fine flocculent amorphous dust. Siliceous remains are in small amount. These authors especially emphasize the importance of algae as sand builders. Wyville Thomson ('77) describes the bottoms in from four to ten fathoms as coral muds and sands, composed of the triturated fragments of algae, corals, and polyzoans, together

MAP 3.



Map of middle third of Bermuda Islands, based on Ordinance Survey Map of 1902. Latitude and longitude ruled to 10 seconds. Scale about 0.9 inch to one statute mile.

MAP 4.



Map of southwest third of Bermuda Islands, based on Ordinance Survey Map of 1902. Latitude and longitude ruled to 10 seconds. Scale about 0.9 in. to one statute mile.

Castle Harbor, which is an excellent example of one of these large submerged sinks, communicates with the sea through several channels, so that it is comparatively open. The main portion of the harbor is about three miles in diameter, is nearly round, and has a greatest depth of about seven fathoms; but the bottom is very uneven. On the south it is separated from the ocean by a chain of small islands, between which there are five narrow channels. On the northwest the enclosing wall is more nearly complete, being broken in only one place, — by the body of water known as Ferry Reach, a partially artificial basin nearly cut off from the harbor by a causeway and an island, but communicating on the west with the open water of the great lagoon, and on the northeast with the passage known as Stocks Harbor. Through this passage Castle Harbor connects directly with St. George's Harbor and through it with the outer lagoon. Thus Castle Harbor, communicating with the sea on three sides, combines the advantages of a protected location and a free circulation of water, making it a very favorable locality for many marine organisms. The bottom is of clear white sand, interrupted by numerous ledges covered with corals, millepores, and coralline algae.

A sample of this sand from Station No. 356, near Castle Island, shows the following composition. It is white, slightly flecked with pink and yellow, slightly coherent, sticky; with 20 per cent of fine flocculent amorphous calcareous ooze. Foraminifera are a striking feature, forming 40 per cent or more of the mass; particularly abundant are the large sand-dwelling genera Orbitolites, Orbiculina, and Ammodiscus. A partial list comprises Orbitolites duplex, Orbiculina adunca, Ammodiscus tenuis, Cornuspira foliacea, Pulvinulina menardii, and species of Polystomella, Trochammina, Textularia, Cyclammina, Cassidulina, Biloculina, and a very few Globigerinae. The great majority of them are living, though there are in addition many dead tests and casts. Most important after the Foraminifera are the coralline algae Udotea and Halimeda, which Agassiz ('**88**[a], p. 82) has also described as occurring in great masses on the Florida Reef. In this particular sample they form only about 10 per cent, but in certain parts of Castle Harbor they grow in such great abundance that their remains form 30 per cent to 40 per cent of the sand. Living mollusks and their shells, mostly fresh and little worn, form 10 to 15 per cent, the most important genera being the gasteropods Bulla, Codakia, Nassa, Cardium, Gouldia, Rissoina, Olivella, Modulus, Bittium, Cadulus, and Vermetus, and the bivalves Crasinella, Abra, Macoma, Semele, Arca, Lasaea, and Tellina. The remainder consists of serpuline fragments, of millepore, bits of coral, echinoid plates and spines, starfish pedecillariae, holothurian plates, sponge spicules, and a few diatoms. The fine flocculent dust or ooze, mentioned above as forming 20 per cent of the sample and giving it a sticky consistency, is composed of exceedingly minute amorphous calcareous particles. It is identical with the ooze, which, in larger deposits, has already been described by Agassiz ('94, p. 52, and '95, p. 253) as "marl," and is undoubtedly produced by the slow triturating action of the sea on aeolian rock. The fine dust thus formed is held so easily in suspension in the water that it is carried and deposited, often at a great distance from its point of origin, in all localities where absence of wave action or currents allows. It is present, in greater or less degree, in every bottom sample from the Bermuda Bank.

As a whole, this bottom contains a great number of living organisms, and the empty shells and shell fragments are fresh and but little water-worn — good evidence that they are of very recent deposition. But at Station 1412, at about the centre of Castle Harbor, in four fathoms of water, the proportion of fine calcareous silt is very much greater, living organisms are less numerous, and the whole sample has a much more water-worn appearance; while the honeycombed condition of most of the dead shells shows that solution by the sea water is here of some importance. This sample was taken from a small basin nearly surrounded by shoals and ledges, where so much of the fine detritus formed by the mechanical action of the water on these aeolian rocks, together with the various organic remains, is being constantly deposited on the floor of the basin that it effectually chokes most of the living organisms. In such regions as Castle Harbor, and, in fact, over most of the Bermuda Plateau, where the sea water always holds a vast amount of calcareous silt in suspension, fixed and sand-dwelling organisms, such as mollusks, tube-building worms, bryozoans, and hydroids, reach an extensive development only on such bottoms as have an active circulation of water that prevents the rapid deposit of silt.

Castle Roads is a good example of the deeper channels connecting Castle Harbor with the open sea on the south. This passage is about four hundred yards wide, with a greatest depth of about six fathoms, and during both incoming and outgoing tides a strong but not violent current runs through it.

The bottom at Stations 409 and 1413, in five fathoms, is a rather coarse shell sand, containing many large fragments; most of the organisms are macroscopic. It is white, spotted with pink; very clean, with less than 1 per cent of fine ooze. Foraminifera of the same species as increasing rapidly toward the mouth; a sample from the middle of the opening (Station 1409, four fathoms), just at the mouth, has only a very faint bluish tinge. It is rather coarse, clean, granular, with 1 per cent fine silt. Foraminifera make up 10 per cent, and millepores and algae, in nearly equal proportion, about 40 per cent; the remainder consists of bivalve and gasteropod fragments, Serpula, Polyzoa, echinoid fragments and small water-worn fragments of limestone from the cliffs. There are many living organisms in this bottom, especially Foraminifera and gasteropods, but the greater portion of the deposit consists of the coarser reef detritus from the neighboring ledges.

Mullet Bay, on the northwest side of St. George's Harbor, is a small nearly enclosed body of water cut off by a very shoal bar and with no tidal currents. The depth over the bar is about seven feet, that inside the bay nearly three fathoms. The bottom (Station 355) consists of a sticky and very fine blue mud, which is chiefly if not entirely calcareous. The fragments of which it is composed are so minute as to be wholly indistinguishable to the naked eye. Large numbers of Toxopneustes live in this mud, and it contains great quantities of their plates and spines, but there are few if any other conspicuous living organisms. The character of the mud shows conclusively that it is chiefly terrigenous silt and detritus washed down from the surrounding hills, and it corresponds perfectly in its occurrence and origin to the siliceous "blue mud" of the continental slope, its calcareous nature being of course explained by the fact that the land mass consists entirely of limestone rocks.

Dolly's Bay (Station 1408), another partially landlocked bight of a similar character, has a bottom of the same type consisting almost entirely of sticky blue mud, with a few echinoid plates and spines. In Smith's Sound (Station 1407), which connects Dolly's Bay with St. George's Channel, the bottom is of similar constitution, but much coarser, with a considerable number of both broken and living shells and an appreciable proportion of the spicules of calcareous sponges, gorgonians, and holothurians.

A glance at the maps shows the close correlation between the bottom deposits and the topographic features in the Castle Harbor and St. George's Harbor regions. In Castle Harbor we find a large body of water, of moderate and fairly uniform depth, in rather free communication on two sides with the sea, and with a free circulation of water, though without strong tidal currents. Under these favorable conditions there is a considerable development of stony corals, gorgonians, and millepores; mollusks, worms, and echinoderms also flourish in great numbers. These living organisms, particularly mollusks, millepores, and Foraminifera, are adding constantly to the bottom deposits, except in some parts of the basin, where silt from the limestone ledges is deposited in such large quantities as to practically choke them. In the deep channels on the south, such as Castle Roads, the tidal currents, setting now in one direction and now in the other, make conditions for sedentary animal life still more favorable, by the great access of fresh sea water and the continual scouring which they effect. In St. George's Harbor the conditions are somewhat different. This is much more nearly enclosed, and the channels which connect it with Castle Harbor and with the outer lagoon are very much shoaler than its main basin, the result being that the circulation of water is not rapid, and a considerable quantity of terrigenous detritus settles to the bottom, giving the sand its characteristic gray color. This detritus, added to the calcareous silt from the outer lagoons, is in sufficient quantity to prevent any very active development of animal life on the bottom. In Dolly's Bay and Mullet Bay the same process has gone so much further that the whole bottom is covered to a considerable depth with the blue mud, which is chiefly of terrestrial origin. In St. George's Channel the tidal current is strong enough to scour the bottom of most of this fine material, leaving little but the large fragments.

The much larger basin at the western end of the islands, known as Great Sound, agrees, in many of its topographic features, with Castle Harbor. Like the latter, it probably originated as an enormous sink, which, through the combined action of subsidence and of the denudation of its surrounding hills, has become open to the sea. In its present form it is open on the north by a passage about a mile and a half broad, and on the west by the narrow cuts which separate Ireland Island, Somerset Island, and the main island. The southern part of this large basin is practically cut off by several small islands, forming the smaller basin known as Little Sound, while Hamilton Harbor forms a narrow arm on the east. The greatest depth of Great Sound, about eleven fathoms, is near its southern border; passing thence northward, the water shoals steadily until at the narrowest point, between Ireland Island and Spanish Point, many of the ledges are nearly awash at low tide, thus forming a natural bar. Through this a narrow ship channel has been blasted.

The character of the bottom in the different regions of Great Sound varies considerably. Near the entrance (Station 459) there are numerous luxuriant patches of gorgonians, sponges, millepores, and corals, which alternate with spaces of white shell sand, composed chiefly of calcareous algae and molluscan remains, with about 10 per cent of fine calcareous silt. Further south, east of Boaz Island and Somerset Island, in a depth of about four fathoms, the appearance of the bottom is altered by the complete absence of coral patches or ledges, although there is still a small amount of living, and a good deal of dead, coral. The bottom samples here consist of white sand, in which fine and coarse material are in about equal amount. The former is about 60 per cent calcareous silt or marl, the remainder being calcareous spicules, together with a great variety of small organic particles. The coarse material consists chiefly of algae, millepores, molluscan fragments, and living mollusks, with worm tubes and echinoid plates. There are very few Foraminifera and few coral remains, although there are a considerable number of millepore fragments. As we go still further southward into the sound, we find the bottom near its southern edge in ten fathoms, composed of sticky white sand of similar constitution but containing a much larger proportion of fine ooze. Apparently this deep basin is a region of deposition for the silt collected by the water on the outer flats.

On the south and east sides of Great Sound, between the different islands, there are several shoal bars where the sand is sufficiently distinctive to be worth special notice. On the bar between Tucker's and Morgan's islands, which forms the southern boundary of Great Sound and the northern boundary of Little Sound (Station 458), in three fathoms, the bottom is whitish, thickly mottled with bright yellow, rather coarse, granular, clean sand, with 6 per cent fine ooze. The yellow color is due to a staining of many of the fragments. Large Foraminifera, of the same genera as those found in Castle Harbor, together with their casts, form about 20 per cent; calcareous algae, bivalves, and gasteropods, 60 per cent; the remainder being composed of Serpula, echinoid spines and plates, millepore, and coral. There are many living Foraminifera and mollusks in this bottom.

The same type of sand, of the same yellow color and with many living mollusks, forms the bars between Godet Island and the main island (Stations 463 and 464), and between Moses and Darrell islands (Stations 456 and 457) on the east of Little Sound; it also forms the bottom off the north and west sides of Elizabeth Island (Stations 455 and 456). But in the channel leading into Hamilton Harbor (Station 421), the sand, though yellowish and almost free from ooze, is much finer, contains very few living organisms, and consists chiefly of water-worn fragments of algae, mollusks, and millepores. It is probably an area for deposition of material from the surrounding shores and shoal bars; but all the finer detritus is scoured out by the tide.

Little Sound, situated directly south of Great Sound and forming a basin about two miles long, with a greatest depth of ten or eleven fathoms, is in many respects similar to Mullet Bay. On the south, east, and west it is bounded by the shores of Long or Bermuda Island; its eastern edge is formed by a broad and very shallow flat, with three small islands; and on the north it is separated from Great Sound by a shoal and narrow bar, over which the greatest depth of water is three fathoms. There is no channel cutting this bar, so that the sound is a practically enclosed basin. The bottom at Station 366, in nine fathoms, is composed of a fine, sticky blue mud, made up of extremely minute particles, most of which are of terrigenous origin. But I was able to distinguish also the tests of a few small Foraminifera, as well as a large number of calcareous sponge and gorgonian spicules, and fragments of Halimeda. The only large fragments were a few broken and water-worn lamellibranch shells, and the bottom contains very few living organisms. It is evident from the nature of the bottom that its origin is very similar to that of Mullet Bay, and that much of the mass consists of terrigenous detritus washed down from the hills which form its southern shore. The topography of Little Sound is such that it has acted as a catch-basin for this material and also for the fine calcareous silt from the outer lagoons and reefs, carried in suspension by the sea water. The absence of living organisms is the result of a choking process caused by the rapid deposition of silt all over the bottom; and in such a locality the remains of resident animals are of very slight importance in forming the bottom deposits.

Hamilton Harbor shows somewhat similar conditions, with a bottom of the same type. There is also another basin of this type which, though very much smaller, has a depth of nine fathoms; it is known as "Granaway Deep," and lies directly south of Marshall Island.

Harrington Sound is more completely landlocked than any of the basins hitherto described. At its southwest corner it connects with the open lagoon through the "Flatts Inlet," a channel barely sixty feet wide, and by several smaller subterranean passages. I cannot make any estimate of the amount of water which passes in and out through these channels, but in certain parts of the sound the tidal currents are of appreciable strength. Strangely enough, in spite of its landlocked condition, this sound is one of the richest localities for invertebrate life; from which we must draw the conclusion that its circulation of sea water is probably much greater than the narrowness of the known passages connecting it with the outer lagoon would indicate. The greatest depth is said by Heilprin ('89) to be sixteen fathoms; most of the basin is from six to ten fathoms deep. The bottom (at Station 404, one fathom), just off the beach at Trunk Island, is grayish white, mottled with red, brown, or yellow; it is composed of coarse sand, the largest fragments 15 mm. in diameter, and about 1 per cent fine ooze. This bottom differs markedly from any hitherto mentioned. There are very few Foraminifera, not more than 2 per cent; echinoid plates and spines, coralline algae, alcyonarian spicules, mollusks, corals, and polyzoans together form not more than 20 per cent; the remaining 75 per cent consists almost wholly of limestone fragments, ranging in diameter from 1 to 15 mm., of rounded and irregular shapes, and variously stained red and brown. They are the coarsest detritus from the neighboring cliffs.

In four fathoms of water, between Rabbit Island and the shore (Station 470), the sand is of the same color and composed of the same elements, but much finer, and with 5 per cent fine ooze. There are no large fragments, and the particles are of fairly uniform size, 1–5 mm. in diameter. The sand decreases in coarseness from shoal water near the shores to greater depths, with an increase of fine ooze; a sample from eight fathoms consists of very fine sand with 30 per cent ooze, and a few large fragments of dead coral. Living organisms seem to have added very little to the sands of Harrington Sound. The undercut and water-worn condition of the cliffs, and the huge limestone masses recently detached from them, bear witness to the effects of surf action on soft friable limestone, even in so limited an area as the Sound. Enormous quantities of detritus, both coarse and fine, must be constantly added to the beaches, the former remaining in shallow water, the latter being swept out and gradually deposited in greater depths beyond the reach of wave action. The bottom in this sound is more extensively derived from broken-down limestone than that of any other extended area which I have examined, and I believe that it is being added to with greater rapidity.

The most important and widespread of all the formations of sand that are now taking place occur on the northern side of the main islands, between them and the nearly continuous boundary reef. Both Heilprin and Agassiz have shown that this area consists of a series of sunken lagoons, bounded by more or less continuous ridges, the "Flats." At only one spot, the "North Rocks," do any of the flats rise above sea-level, but the depth in many places is so slight that they are nearly awash at low tide. The numerous ledges and shoal patches, although covered by a luxuriant growth of corals and gorgonians, are not of coral origin, but are ledges of the ordinary aeolian rock, over which the corals and other organisms are growing, and they furnish a great deal of material to the bottom sands. The depths of the lagoons are fairly uniform and moderate, being nowhere over twelve fathoms. The more important lagoons from which I have examined samples are Mangrove Bay, the Cow Ground Flats, Green Bay, Murray Anchorage, the Ship Channel, and Brackish Pond Flats.

Mangrove Bay, though open to the sea, is nearly surrounded by Somerset Island and, on the north, by a shoal flat, making it another enclosed catch basin, with a greatest depth of six fathoms. The bottom at Station 319, in five fathoms, is fine gray sand, containing many large fragments of millepore and oculina, evidently washed from the neighboring flat. The bulk of the sand consists of broken shells, sea-urchin plates and spines, and fragments of worm tubes, with about 20 per cent of very fine calcareous silt. The presence of great numbers of the calcareous spicules of sponges and gorgonians, and of the tests of small Foraminifera, show that it is of reef origin ; a small proportion of it, however, is apparently terrigenous silt, or "blue mud," and there are few living organisms. Most of this bottom is evidently derived from the surrounding shoals, being composed of various animal remains, together with a large amount of the fine silt resulting from the erosion of the limestone ledges. The rest of the material is of terrigenous origin, and resident organisms have had little or nothing to do in the formation of the deposit.

Murray Anchorage is the largest of the submerged lagoons, covering an area of about ten square miles. It extends from the shores of St. George's Island on the southeast to the Three Hill Shoals on the north, a distance of three or four miles. On the southwest it is bounded by Bailey's Bay Flats, and on the northeast by the boundary reefs to the north of St. George's Island. The bottom is level, with very few shoals or ledges, and the greatest depth, in the Ship Channel on the southern edge of the lagoon, is ten fathoms. The deposits over the bottom of the lagoon vary considerably in character in different localities, although they are everywhere white sand. North of Murray Anchorage, between Three Hill Shoals and the boundary reef at Station 324, in ten fathoms, this white sand consists of exceedingly minute particles, and has the appearance of a white, chalky ooze. Fragments of algae, millepores, and gasteropod and lamellibranch shells, with a few echinoid fragments and pieces of worm tubes, are distinguishable; also a few Foraminifera. Over 70 per cent of the mass, however, consists of minute calcareous particles, forming a true marl. There are very few living organisms of any kind on this bottom, and their remains have added but slightly to it. The fine silt consists of the detritus from the destructive action of the water on the surrounding limestone reefs and ledges. In the southern and southeastern part of the lagoon, through which the Ship Channel runs, the character of the bottom is very different. We find here also, at Station 1416, in seven fathoms, a white sand, but it is much coarser, containing large quantities of corallines, molluscan shell fragments, and many living bivalves and gasteropods, with bits of worm tubes, plates of echinoids, millepore fragments, and a few large Foraminifera, chiefly Orbiculina and Orbitolites. There is about 10 per cent of fine calcareous silt, containing some spicules of sponges and gorgonians, which is similar in nature to the white marl of the northern half of the lagoon. This shell sand extends westward along the Ship Channel, at a depth of about eight fathoms, into the so-called "Brackish Pond Flats," directly north of the Flatts Inlet. In this inlet itself (Station 393), the very strong tidal flow has effectually scoured out all the finer materials, leaving only the coarser fragments. From the Ship Channel southward toward Crawl Point and Bailey's Bay, the water gradually shoals to about four fathoms; about a mile off shore, in seven fathoms (Station 00 ?), we again find the white marl bottom already described for the region north of Murray Anchorage. There are here more large shell fragments and more living Orbitolites and Orbiculina than in the more northern area, but organisms in general are very few. The proportion of calcareous sponge and gorgonian spicules is considerable; the rest of the deposit, about 60 per cent, consists of very fine water-worn silt.

Still nearer the shore, around the ledges known as the "Pigeon Rocks," about half a mile from Crawl Point, at Stations 411, 412, and 416, in about three fathoms, shell sand again occurs, the bottom being very clean, with less than 5 per cent ooze, though varying much in coarseness, some of it being very fine indeed. The transition from marl, at Station 00 ?, to this deposit of sand is very sudden, and is no doubt due to the shoaling water and the surf action around these detached ledges. About one mile to the eastward, at the mouth of Bailey's Bay (Station 317) in two to three fathoms the bottom is again coherent, having 30 to 40 per cent ooze and being light gray. The coarse material consists chiefly of molluscan fragments and Foraminifera, with a few living bivalves, gasteropods, and fragments of echinoids and corallines. This station and the Bay itself are sheltered localities, where fine silt is readily deposited.

Close in along the shores of the main or Bermuda Island and St.

George's Island, in one to three fathoms, the bottom is again shell sand. Thus, just off St. Catherine's Point (Stations 438, 439, 440, and 441), in from one to two fathoms, the bottom is very clean, the sand being very coarse, white with a faint yellowish tinge, and with less than 1 per cent of ooze. Foraminifera form less than 10 per cent, and the great bulk, probably 50 per cent, of the sample consists of coralline and millepore fragments of large size, the remainder being mollusk shells, echinoid plates, Polyzoa, corals, and limestone fragments. The fragments are all much water-worn and honeycombed, and there are very few living organisms in the bottom. In this neighborhood there are many detached ledges, and in the shoal water along shore, where the scouring action of the waves is considerable, the bottom consists almost wholly of the coarse detritus from them, and from the shore cliffs.

In all other parts of the submerged lagoons, except those already described, the bottom deposits consist of shell sands and marl, occurring together in varying proportions. But in such of the lagoons as are broken by great numbers of small reefs, the proportions in which these two materials occur often differ widely in closely adjacent localities. In such basins the depths over the floor are usually very uniform, and the shoals and ledges rise very abruptly to near the surface. Their walls are often nearly perpendicular, very much honeycombed, and often undercut by the action of the water. Examples are the Brackish Pond Flats, the flats north of Ireland Island, and the Cow Ground Flats, two miles west of that island. The Brackish Pond Flats occupy the centre of the Bermuda Plateau, and consist of a perfect maze of shoals, deep channels, and basins. At different stations the bottom deposits are very different. Thus at Station No. 359, three miles northeast of the dockyard, in five fathoms of water, it is chiefly shell sand, composed of large living Foraminifera in great abundance, particularly Orbiculina, Orbitolites, and Pulvinulinae, molluscan fragments, living lamellibranchs and gasteropods, millepore fragments, a few coral fragments, worm tubes, corallines, and calcareous spicules, with about 25 per cent of very fine calcareous silt. At another station (No. 383?), in a small basin one mile directly north of the last, in seven fathoms of water, the bottom consists almost entirely of white marl, but contains also a considerable amount of broken shells and calcareous spicules, although very few living organisms. On the Cow Ground Flats the topographic conditions are very similar. At a station one mile directly west of the dockyards, in a cut between the ledges eight fathoms deep the bottom was white and coherent, with 80 per cent fine ooze or marl, the remainder being chiefly corallines and millepores from the nearby ledges, with a few molluscan and other fragments.

Hogfish Cut is the only one of the several channels penetrating the boundary reef from which I have examined bottom samples. The collection contains five of these, from as many localities between the cut and the shore (Stations No. 430, 431, 434, 460, 461), which are almost indistinguishable. They are very clean, fine shell sand, whitish, with a faint pinkish tinge, with less than 1 per cent ooze. Although so clean, the sand itself is as fine as the bottom at Nonsuch Scaur. Foraminifera and their casts, especially Polystomella, form about 15 per cent; the remainder consists of corallines, mollusks, millepores, corals, ostracods, echinoderm remains, and Serpula tubes. There are very few living organisms of any kind in this sand, which resembles sand from Nonsuch Scaur so closely as to be almost indistinguishable from it.

From the area of the bank outside the boundary reef, between it and the thirty-fathom line, I have, unfortunately, no samples, and my only information is derived from the reports of fishermen and from what little could be seen through the water glasses. The vigorous growth of corals, gorgonians, millepores, etc., on the ocean faces of the reefs extends down to only about six or seven fathoms. Here begins the "broken ground" described by Agassiz (:95), as composed of various fragments and detritus from the reef itself, together with great numbers of nullipores. At about fifteen fathoms large sand patches appear, and in twenty fathoms the bottom is chiefly sand (admiralty chart).

GENERAL CONSIDERATIONS.

The study of these samples of sand from the shoal lagoons of the Bermuda Plateau is chiefly of interest for the light which it may throw on the method of growth of a limestone island in a latitude where reef-building corals are of but slight importance, and on the organisms chiefly concerned in this growth. The Bermudas, from their superficial resemblence to an atoll, and from the fact that their reefs are largely covered with corals, were considered as typical coral islands until the time of Agassiz's visit in 1895. It is from this point of view that Heilprin ('89) describes them, and Rein ('81) uses them as an example of an atoll in combating Darwin's theory of subsidence. Agassiz ('95) has, however, shown beyond possibility of doubt that this resemblance to a coral formation is purely superficial, that their ring-like form is due, not to coral growth, but to entirely different causes, and that coral has entered but slightly into their formation; a conclusion which is supported by the composition of the modern sands.

The oceanic character of Bermuda — its great distance from the neighboring continent — prevents, as might be expected, its receiving any important access of material from the continental slope, and consequently its submarine deposits consist almost entirely of materials of clearly local origin. The great scarcity of remains of pelagic organisms, Globigerinae, Radiolaria, Pteropoda, and the like, is a striking feature of all the bottom samples examined; and this is especially interesting in connection with the results of our pelagic towing, from which we were forced to conclude that the pelagic fauna of Bermuda, on the north side of the islands at least, is very poor, both in species and individuals. On the southern exposure of the bank the conditions might prove to be different. But by far the greater area of the bank lies north of the land crescent, which forms an effectual barrier against any surface currents which might be caused by the prevailing southerly winds. Castle Harbor is the only sound to which water from the south has free access, and it is interesting to note that several tropical pelagic organisms, such as Velella, Charybdea, etc., have been taken here, but never on the northern side of the islands, while some species of fish are also known to occur only on the south shore. Shells of Spirula, however, are found in considerable numbers on all of the beaches. The only objects found which might possibly be of volcanic origin were a few small particles of pumice.

The great bulk, at least 90 per cent, of all the bottom deposits, whatever their nature, is composed of calcareous material. Siliceous materials are exceedingly small in amount, and consist chiefly of the spicules of various organisms, there being no siliceous particles of terrigenous origin.

One of the most striking features of all the beaches and submerged sands is the complete absence of any true coral sand, and the great rarity of coral fragments of any kind. This is, of course, strictly in agreement with the fact that the Bermudas are in no sense a coral island, and that coral has had practically nothing to do with their formation and growth. Corals, of course, flourish on the reefs, but form merely a thin incrustation over the underlying aeolian ledges. That they do not enter more largely into the sands is due chiefly to the character of the forms occurring here. In all coral islands and coral reefs it is the madrepores which are chiefly responsible for the formation of sand, these being delicate and easily broken up. But here, as observed by Agassiz ('95, p. 235), the corals are mostly gorgonians, which are of course of no importance in that it results in the choking of all organisms on the bottom, except where tides or waves sweep it away. A good example of such distribution of deposits is seen in Murray Anchorage, where, in the sheltered northern half, the bottom is almost wholly marl, while in the Ship Channel near by there is a strong tidal current and a bottom of shell sand. A striking example of the silting in of sedentary organisms was found by Herdman (:03) in his study of the pearl oyster beds of Ceylon, where, during a single year, a bed of several millions of young oysters was destroyed and entirely hidden by shifting sands.

Heilprin ('89) emphatically denies the supposition that solution can have any significant effect in keeping the lagoons and channels open; it is certain that the marl and shell sand are building up and levelling the surface of the plateau much faster than the water can possibly dissolve it, by which, however, I do not mean that the surface of the bank is as a whole rising. Agassiz ('95) has already shown the great importance of the solvent action of sea water on limestones in honeycombing and undermining cliffs and ledges, and in certain localities the same action is clearly shown in the worn and honeycombed condition of the shells and other fragments in the sand.

List of Stations at which Bottom Samples were collected.*

1903.

No.				Map No.
313.	64° 43′ 47″ W.;	32° 20′ 18″ N.	Off Crawl Point, 5 fathoms.	3
314.	64° 42′ 50″ W.;	32° 20′ 45″ N.	N. of [Bailey's] Bay Id., 8 fms.	2
317.	64° 43′ 03″ W.;	32° 20′ 30″ N.	Mouth of Bailey's Bay, 3 fms.	3
319.	64° 51′ 07″ W.;	32° 18′ 10″ N.	Mangrove Bay.	4
323.	64° 50′ 32″ W.;	32° 19′ 24″ N.	West of Ireland Id., 7 fms.	4
324.	64° 43′ 50″ W.;	32° 25′ 15″ N.	Three Hill Shoals, 8½ fms.	1

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* The position of each of the various stations is indicated on the accompanying maps by two marginal lines, one for latitude and one for longitude. After the maps were prepared it was discovered that there was a discrepancy of about 20″ in latitude between the British Admiralty Chart, on which Map 1 is based, and the recent Ordinance Survey Map, on which Maps 2–4 are based. A correction of *plus* 20″ is to be applied to the *latitude* of any place indicated on Maps 2–4 to bring it to the corresponding place on Map 1; or a correction of *minus* 20″ to places on Map 1 to make them fall at the right place on Maps 2–4.

The location of any given station was determined on one or other of these maps, and the latitude and longitude here recorded is that of the given place *on that map*. Where the haul extended over some distance, the middle point of the haul is the one noted on the map. — E. L. M.

355.	64° 41′ 05″ W.;	32° 22′ 05„ N.	Mullet Bay.	2
356.	64° 40′ 30″ W.;	32° 20′ 40″ N.	(approximately). Centre of Castle Harbor, 6 fms.	2
359.	64° 46′ 10″ W.;	32° 21′ 10″ N.	Brackish Pond Flats, 5 fms.	1
366.	64° 50′ 12″ W.;	32° 15′ 17″ N.	Little Sound, 9 fms.	4
1407.	64° 38′ 58″ W.;	32° 21′ 45″ N.	Smith's Sound, 4 fms.	2
1408.	64° 39′ 15″ W.;	32° 21′ 36″ N.	Dolly's Bay, 3 fms.	2
1409.	64° 38′ 57″ W.;	32° 21′ 56″ N.	St. George's Channel, 4 fms.	2
1413.	64° 39′ 40″ W.;	32° 20′ 05″ N.	Castle Roads, 5 fms.	2
1416.	64° 44′ 00″ W.;	32° 21′ 10″ N.	Ship Channel, near Crawl Flats, 6½ fms.	1
1417.	64° 43′ 18″ W.;	32° 22′ 21″ N.	South Side of Murray Anchorage, 8 fms.	1
1418.	64° 42′ 18″ W.;	32° 22′ 38″ N.	South Side of Murray Anchorage, 8 fms.	1

1904.

383.	64° 47′ 45″ W.;	32° 22′ 20″ N.	Brackish Pond Flats.	1
393.	64° 43′ 59″ W.;	32° 18′ 59″ N.	Flatts Inlet.	3
402.	64° 42′ 15″ W.;	32° 21′ 13″ N.	W. Entrance Ferry Reach.	2
404.	64° 43′ 02″ W.;	32° 19′ 35″ N.	Harrington Sound.	3
406.	64° 38′ 47″ W.;	32° 21′ 57″ N.	Entrance St. Geo. Channel.	2
407.	64° 39′ 12″ W.;	32° 20′ 33″ N.	Nonsuch Scaur.	2
408.	64° 39′ 08″ W.;	32° 20′ 28″ N.	Nonsuch Scaur.	2
409.	64° 39′ 40″ W.;	32° 20′ 00″ N.	Castle Roads.	2
411.	64° 43′ 20″ W.;	32° 20′ 28″ N.	Near Pigeon Rocks.	3
412.	64° 43′ 30″ W.;	32° 20′ 28″ N.	Near Pigeon Rocks.	3
415.	64° 43′ 45″ W.;	32° 20′ 17″ N.	Off Crawl Point.	3
416.	64° 43′ 22″ W.;	32° 20′ 30″ N.	Near Pigeon Rocks.	3
418.	64° 48′ 27″ W.;	32° 16′ 53″ N.	North Shore of Long Island.	4
419.	64° 48′ 32″ W.;	32° 16′ 52″ N.	North Shore of Long Island.	4
420.	64° 48′ 35″ W.;	32° 16′ 52″ N.	North Shore of Long Island.	4
421.	64° 48′ 10″ W.;	32° 17′ 05″ N.	Two Rock Passage.	4
422.	64° 47′ 55″ W.;	32° 17′ 25″ N.	Mouth of Fairyland Creek.	3
423.	64° 48′ 32″ W.;	32° 18′ 03″ N.	Cobbler's Cut.	4
427.	64° 45′ 10″ W.;	32° 27′ 30″ N.	North Ledge Flats.	1
428.	64° 45′ 10″ W.;	32° 26′ 30″ N.	Northwest of Three Hill Shoals.	1
429.	64° 45′ 10″ W.;	32° 25′ 20″ N.	West of Three Hill Shoals.	1
430.	64° 52′ 20″ W.;	32° 15′ 03″ N.	Hogfish Cut.	4
431.	64° 52′ 18″ W.;	32° 15′ 12″ N.	Hogfish Cut.	4

lipores that were dead; this side evidently had recently been undermost. They thus agree exactly in external appearance with the "pebbles" of the Challenger. But while both Thomson and Murray believed them to be composed of the same material as the Bermuda serpuline reefs, that is, of aeolian limestone, careful examination has shown them to be of an entirely different origin. When sawed into slices, the sections show that the pebble is composed of successive, more or less regularly concentric layers of Lithothamnion, together with a few worm tubes, bryozoans, and other incrusting organisms. The whole mass is more or less porous, often honeycombed by the borings of mollusks (Lithophagus), and the looser regions alternate with more compact layers. The mode of growth has evidently been that of successive depositions of lime by nullipores around some small central core, which may be very minute. This is not, of course, in any sense of the word a pebble, but is a true nullipore "head," in no way to be confounded with either aeolian pebbles or the mechanical concretions of lime or siliceous materials so often dredged in deep water.

The spherical form of these heads is of considerable interest. Such spherical nullipore masses occur very commonly in shoal water, either as concretions about some core, or as independent stalked growths, which eventually become detached and free to roll about. Such forms have been taken in great numbers off Eastport, Me., in a few feet of water, and also in many other localities where they are well within the sphere of wave action, and probably owe their spherical form to the fact that they are frequently rolled over and over. Such spherical masses have also been previously dredged in deep waters, where their mode of growth has been something of a problem. That some such process of wave action is at work on the Challenger Bank seems probable from the spherical form and worn appearance of the concretions, the latter condition being made evident by the broken nullipore branches. Without being occasionally overturned they would not attain a spherical form, but would probably take on forms similar to those of porites, astraeans, or other fixed massive corals. To account for the amount of disturbance of the bottom necessary to explain such spherical concretions, we must turn to a consideration of wave action; neither tides nor currents being sufficiently strong in this locality to afford an explanation.

Statements as to the depth to which the action of storm waves may extend are conflicting and unsatisfactory in the extreme. While it is often claimed that one hundred feet marks the limit to which wave action is important in the transference of material, I am assured by Professor

W. M. Davis that the oscillations can probably be detected to a depth of several thousand feet. Moreover, Alexander Agassiz ('88ᵃ, p. 273) writes that off the New England coast disturbing forces due to the action of waves, tides, and currents may extend perhaps to a depth of nearly three hundred fathoms. But in this case currents are probably chiefly concerned. More definite and satisfactory are the opinions of Admiral Wharton ('97), who has suggested that the depth to which the action of waves extends may be indicated by the change of slope generally taking place off shore below a depth of eighty to one hundred fathoms; and, further, that the existence of banks in the open sea at a depth of from thirty to forty fathoms may show the limit of depth to which oceanic waves may cut down a land mass on which they act. Agassiz (:03ᵃ, p. xviii.) also thinks there is good evidence of such submarine denudation. At first glance the Challenger Bank seems to present a good example of such a worn-down bank; dredging has shown, however, that its surface is not undergoing a process of denudation, but rather one of growth.

If we can accept Admiral Wharton's conclusions, — and they rest upon a much sounder basis than the earlier views which limited wave action to lesser depths, — we shall find in wave action, and especially in the oscillations of storm waves, a sufficient explanation for the present problem. I am convinced that the frequent movements of the nullipore concretions, which undoubtedly occur, are brought about in this way; and I consider the occurrence of such spherical concretions on the bank good evidence that at a depth of from thirty to fifty fathoms the action of storm waves is often of considerable force.

The dredgings from the Challenger Bank add to the evidence already accumulated to prove the great importance of nullipores as reef builders. The active rôle which they play in the economy of coral reefs, especially on the sea faces, and in localities where the corals are dead or dying, has been emphasized by Agassiz ('88ᵃ, p. 82), who, writing of the Florida reefs, says, "Immense masses of nullipores and corallines grow on the shallowest flats at the tops of the branches of madrepores which have died from exposure to the air." J. Stanley Gardiner ('98, pp. 501, 502), in his studies on the island of Funafuti, also comes to the conclusion that they take a very important part in the building up of a coral reef. They are not, however, limited to shallow waters, but occur at considerable depths, being absolutely limited only by the absence of sunlight. Thus Agassiz ('88) found them smoothing over the modern limestones on the Pourtales Plateau, in depths of from ninety to three hundred fathoms, and in the borings at Funafuti nullipores seem to be the most important of all rock-building organisms, even at the extreme depth of 1120 feet, a depth of course well within their ordinary bathymetric distribution, as shown by the Pourtales Plateau. Apart from the considerable amount of material which they may add to any shoal, the great importance of the incrusting nullipores lies in their solidifying and cementing action. Thus, on the sea face of a reef, they are most effective in protecting it against the force of the surf, as, for example, in the case of the Bermuda serpuline reefs, a function which they share chiefly with the tube-building annelids. In the upbuilding of submarine banks they carry on a very similar process. The events now going forward on the Challenger Bank are probably as follows. The nullipores gradually form incrusting masses about various objects, or grow up independently on stalks which later become broken; in these ways the spherical concretions begin. Lying free on the bottom, subject to the action of the waves, they are occasionally turned during their growth so that they retain a spheroidal form, until at last they can no longer readily be moved; whereupon, lying motionless side by side, they become cemented together by the incrusting organisms, and thus come to form a solid modern limestone, which is produced much more rapidly than that which is formed from the loose shell sands. This process taking place over the Challenger Bank, where there is no direct evidence of either elevation or subsidence, has raised it to within some thirty to fifty fathoms of the surface of the sea; a depth where a few corals already flourish. If we imagine this process as continuing until the bank rises to within about twenty fathoms of the surface, we should then have excellent conditions for the formation of a coral reef. Of course in such upbuilding the nullipores constitute only a part, though a most important one, of the whole growth; the tests of Foraminifera, and the remains of other lime-secreting organisms, add largely to the accumulation of material.

The reports of the borings in Funafuti, a true coral island of the Ellice group, recently published (Bonney and others, :04) by the Royal Society of London, are of special interest in this connection. After two unsuccessful attempts, the drill was finally driven to a depth of 1114 feet, and the cores have since been carefully studied. Dr. G. J. Hinde has given (pp. 186–361) an elaborate account of the organisms; and the evidence goes to show that whether in the form of solid rock cores, or as incoherent granular particles, the material is entirely of organic character, traceable to the calcareous remains of animals and algae, of which Halimeda and Lithothamnion occur in greatest abundance. Professor Judd remarks that "from top to bottom the same organisms occur, sometimes plants, sometimes Foraminifera, and sometimes corals predominating"; and Mr. Finckh (p. 133), studying the biology of these reef-forming organisms, judges their relative importance to be in the following order: (1) Lithothamnion, (2) Halimeda, (3) the Foraminifera, (4) Corals.

In dredging on the sea slopes of the Funafuti atoll Lithothamnion was found abundant down to two hundred fathoms, and it plays a very important rôle in the modern reefs. One observation of particular interest was on the growth of a cluster of Halimeda (p. 146), which in six weeks attained a height and thickness of three inches.

The most interesting feature of the report, as far as concerns our study of the Challenger Bank, is the very great importance attaching to the coralline algae, both in the modern reefs and in the older rocks, as shown by the core from the borings. Putting aside all question as to changes of level of the sea floor, there can be no doubt that the corallines, with slight aid from other organisms, are capable of building limestones of great thickness; and I believe that they will be found to enter into the composition of most limestone banks, particularly those which, like Bermuda and the Challenger Bank, lie outside the belt of vigorous coral growth. To complete the survey of what I may call the "Bermuda range," it is most desirable that an examination should be made of the Argus Bank, which rises to within eight fathoms of the surface. No doubt, thanks to the shoal water, it will be found much more thickly covered with corals and gorgonians than the Challenger Bank; but in all probability its foundations and structure are the same, and I think we may consider the Challenger and Argus banks as two stages in the growth of such an exposed peak as the Bermudas.

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CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL STATION
FOR RESEARCH.

No. 6.

THE BERMUDA ISLANDS AND THE BERMUDA BIOLOGICAL STATION FOR RESEARCH.

By E. L. Mark.

With Sixteen Plates.

From the Proceedings of the American Association for the
Advancement of Science, Vol. LIV.

CAMBRIDGE, MASS., U. S. A.
February, 1905.

ADDRESS

BY

E. L. MARK,

VICE-PRESIDENT AND CHAIRMAN OF SECTION F FOR 1904.

THE BERMUDA ISLANDS AND THE BERMUDA BIOLOGICAL STATION FOR RESEARCH.

I feel a certain hesitancy in speaking on the subject I have selected to talk about—the Bermuda Islands—because of the number of prominent naturalists who have written so excellently about them. It should be stated at the outset that I do not aim to add to the stock of our knowledge about the Bermudas. So much has been written about their zoölogy in recent years,—especially by the zoölogists of the Challenger Expedition, then by Professor Heilprin of this city, on the invertebrates and the coral reefs, by Mr. Agassiz, incidental to his studies of the great question of the origin and growth of coral reefs, and most recently by that veteran in systematic zoölogy, Professor Verrill, of Yale University,—that it is hardly to be expected that anything fundamentally new will be soon added. It is my purpose, rather, to give something of a picture of the present conditions in Bermuda, based partly on my own experiences, and particularly to direct your attention to the accessibility of the islands and their availability as a place for carrying on intensive rather than extensive researches. With the facilities for work which will soon be provided by the Colonial Government, it should be an attractive place not only for temporary exploration and summer study, but also for protracted investigations on important biological problems.

My own interest in Bermuda as a place for zoölogical study was first awakened by suggestions of President Eliot, who a few years ago passed the winter in Bermuda, and upon his return inquired of me if I did not think it would be a good place for a marine laboratory. The more I inquired into the conditions of living in the islands, and the marine organisms in the sea about the islands, the more I became convinced of the practicability of the place for a biological laboratory.

At the risk of saying much that is already familiar to many of you, I will give an account of some of the things which seem to me of interest in this connection.

From fifty to sixty hours' steaming brings one from New York to Bermuda. It is worthy of note that the distance of the islands from New York or Boston is only about two-thirds that of the Dry Tortugas or the Bahamas. The climate and the conditions of life in the Bermudas are safe and agreeable at all seasons of the year. Though the humidity is considerable, the temperature in summer rises to only 85° or 86° Fahrenheit; in winter it seldom gets below about 50°, and never to the freezing point. To the zoölogist familiar with the animals of our north Atlantic coast and the water they live in, the waters that wash the shores of these islands and the brilliantly colored animals that inhabit them are a source of surprise and delight.

Leaving New York a little before noon on a Saturday, the islands are usually sighted about mid-day on Monday, and landing is made in Hamilton a few hours later. If one has pictured to himself low-lying coral islands fringed with palm trees, he will be disappointed, and will be surprised to find that the land rises in many places to a considerable height,—even to two hundred and fifty feet or more,—and on approaching nearer to see, instead of palms, the dark green of the cedars that cover many of the hills. In passing from the deep waters of the Atlantic to the shallower depths near land, the dark blue of the ocean is replaced by livelier tints, in which greens predominate, and when the conditions of sun and sky are favorable, the variety of colors exhibited is truly wonderful. Even the far-famed Bay of Naples does not afford a more brilliant display of colors than is sometimes seen in the waters around the Bermudas.

In contrast with these fascinating, kaleidoscopic effects of the sea, the land presents either the dull gray appearance so common on the granite shores of New England, or the dark green of the cedars, which also reproduce the effect of the New England evergreens. If one could ignore the colors of the sea, he might easily imagine, as he steams along the northern shores of the Bermudas, that he was skirting some part of the Maine coast. One thing, however, would impress him as strange—the brilliant white specks and patches which here and there dot the hillsides or are clustered into larger or smaller groups—the limestone dwellings of the Bermudians. These, with their white roofs brilliant in the sunlight, are in marked contrast with anything to be seen on the Maine coast. Government House on Mount Langton—the residence of the Governor of the islands—is a conspicuous building on the crest of the ridge which hides the city of Hamilton from the approaching voyager.

After a long and rather circuitous course through the only channel available for steamers, and under the guns of several forts, one at length enters Hamilton Harbor between two rocks that are not far enough apart to allow the passage of two ships abreast. The still unfinished cathedral, two modern hotels for the accommodation of winter tourists, and the parliament house are the most conspicuous buildings in Hamilton, being situated on the highest part of the slope occupied by the town (fig. 1).*

The substantial city dock, with its low, unattractive sheds roofed in by arched and corrugated metal, extends along the whole water front. Beyond the sheds runs Front Street (fig. 3) parallel to the shore. Across the street from the sheds are the chief business houses of the town. Some of them have a modern look, but the greater part of them have small windows and heavy solid wooden shutters that recall the northern country store of fifty or seventy-five years ago. Unlike the country store, however, the Bermuda store has a two-story portico extending out over the side-walk, so that the pedestrian is partly sheltered by it from the heat of the sun or the sudden downpour of the unannounced shower that is so characteristic of the islands. The second story of this portico, like most of the dwellings (fig. 6), is enclosed by shutters with immovable slats, which keep out heat and rain, but permit a free circula-

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* The figures are arranged on plates at the end of this article.

MAP I.

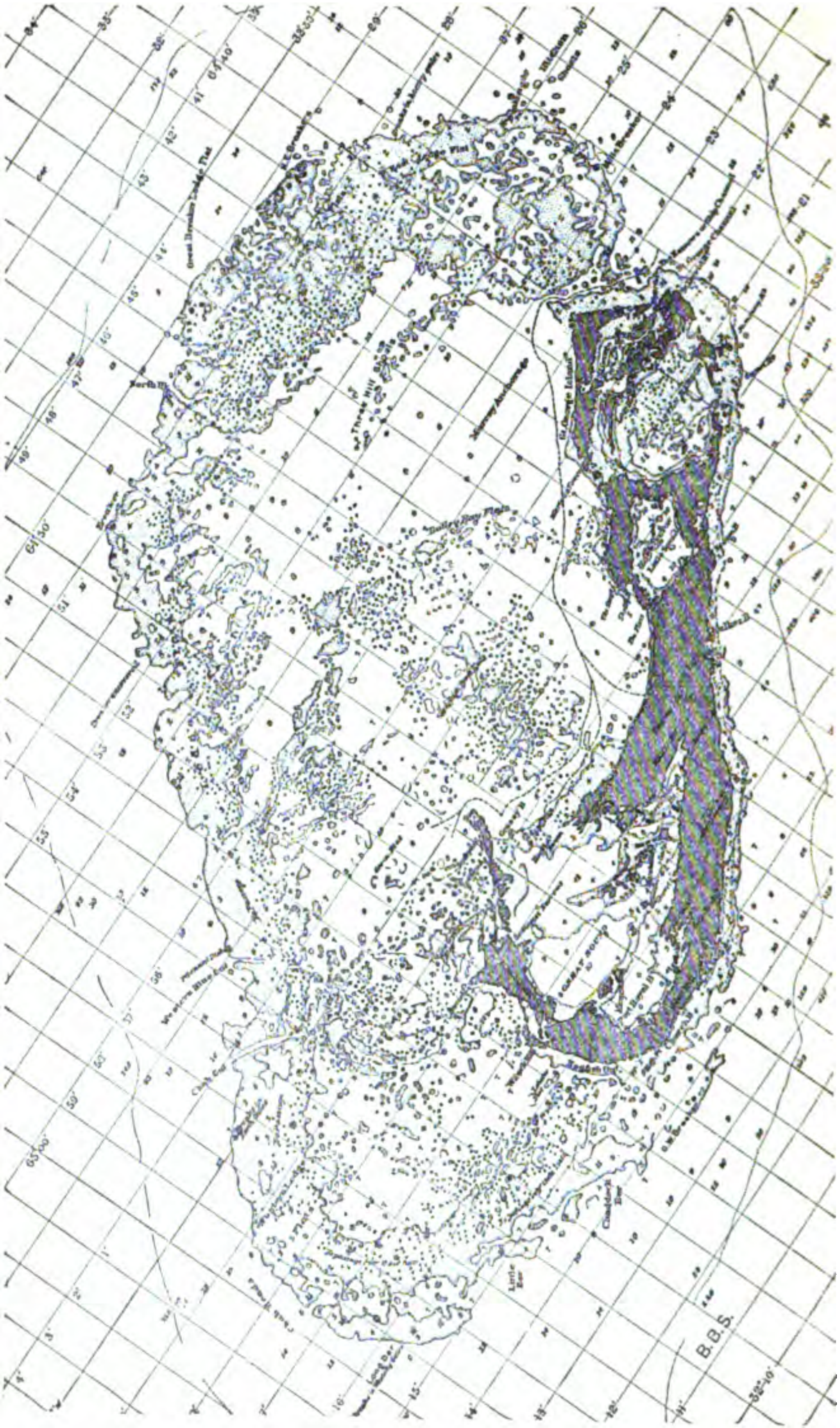
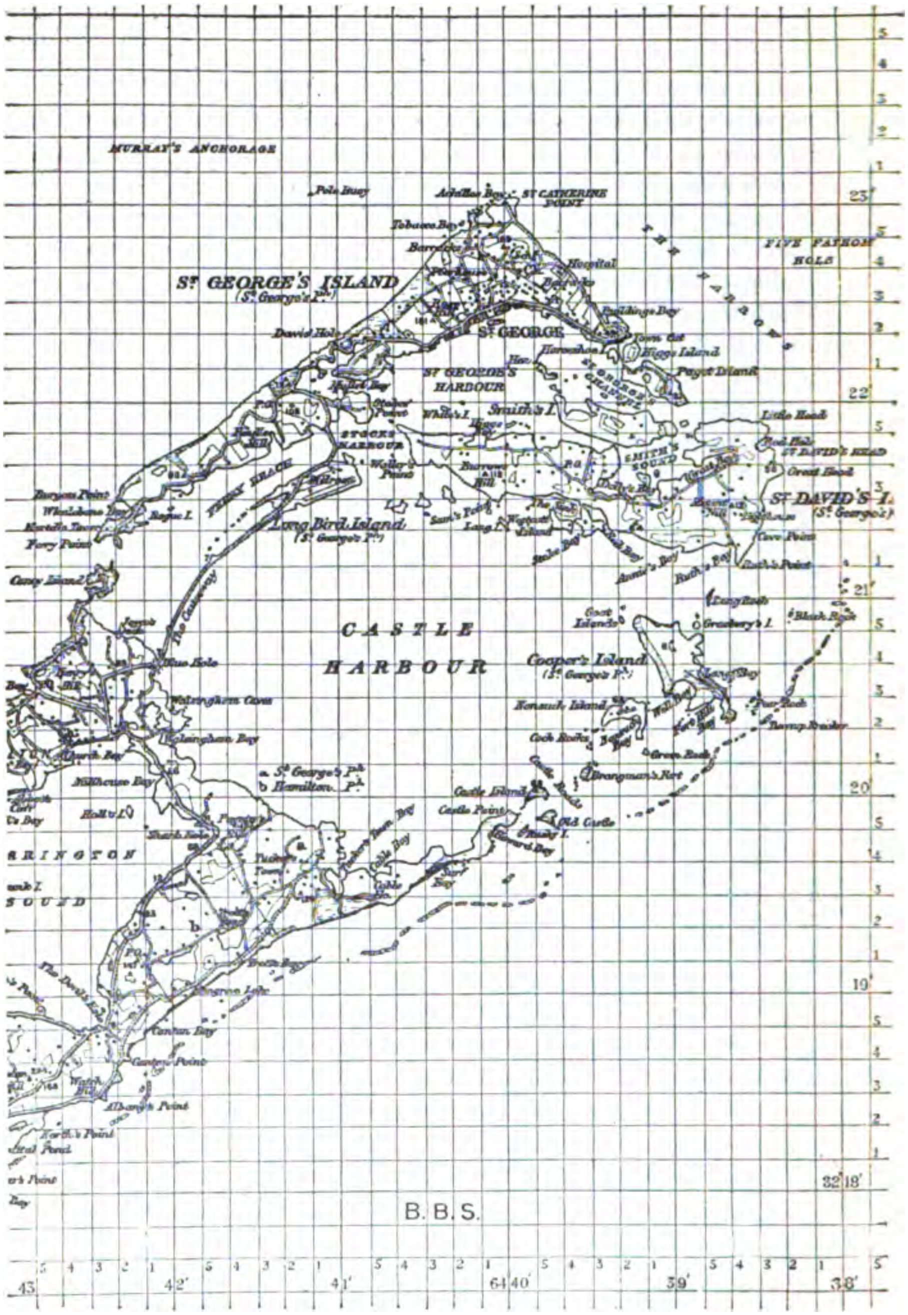


Chart of the Bermuda Islands, with soundings in fathoms, the 100-fathom line (dotted), the ship channel (dashes), and the latitude and longitude to minutes.

tion of air within. The vehicles in the street range from the modern rubber-tired victoria to the low two-wheel cart drawn by horse, mule, or ox.

As a glance at the map will show (map 1), the Bermudas consist of a chain of about half a dozen islands so grouped that the whole bears a fancied resemblance to a gauntlet. The broad wrist region at the northeast is made up of St. David's, Smith's and St. George's islands and a part of the main, or Bermuda, island, the rest of which stands for the hand, the thumb and the first joints of the fingers, the remaining joints of the fingers being represented by Somerset and Ireland Islands. The whole length of the group from northeast to southwest is about fifteen miles, and the width is usually a mile or at most two miles; in many places much less. A fairly continuous ridge occupies the axis of the islands mentioned. Besides these larger islands, there are numerous smaller ones (fig. 15), so that it may well be that there is, as claimed, an island for every day in the year. The larger islands are so indented by bays and sounds that it is evident they will in time become divided up into smaller ones, and thus add to the existing number. The largest of the bodies of water on the north that seem to have eaten their way into the land masses is Castle Harbor (map 2). This lagoon is from two to three miles in diameter, and communicates with the open sea on the southeast by several passages separating from each other as many small islands, and with a great northern lagoon by means of a long arm of the sea called Ferry Reach. Connected with Ferry Reach at its northeasterly end is St. George's Harbor, which affords an excellent and well protected anchorage. Southwest from Castle Harbor, and separated from it by only a narrow ridge, is Harrington Sound, which looks like an inland lake (fig. 20); it is a mile wide, two miles long, and in places sixty or seventy feet deep. This has only one communication with the sea above ground, though there are several underground connections. This single surface-connection is by means of a passage only about thirty feet wide, through which the water rushes with great swiftness during every tide. It is surprising for how short a time at the turn of the tide, five or ten minutes only, the water is relatively quiet. This narrow passage leads directly

MAP 2.



Map of the Northeastern Third of the Bermuda Islands, with latitude and longitude lines ten seconds apart.

to the Flatts Inlet, which in turn connects with the great north lagoon. The Inlet, not being very broad, is therefore swept by a rather strong current. This region ("The Flatts," map 1) is of particular interest to us, for it is on this inlet that our laboratory is located.

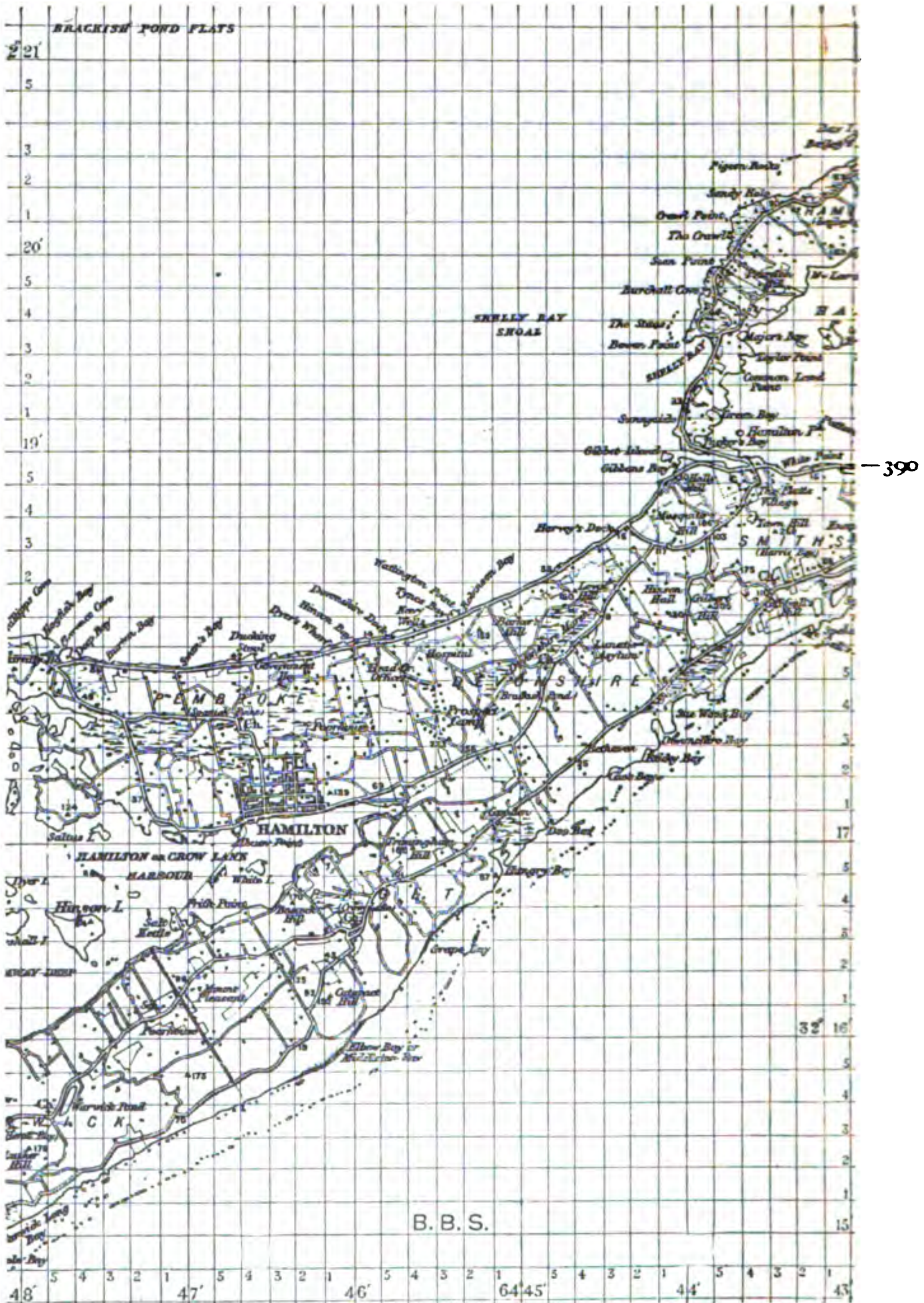
All the waters held, as it were, in the hand of the fancied gauntlet—Great Sound, Little Sound (map 4), Hamilton Harbor (map 3), etc.—form another extensive landlocked sea, which formerly, in all probability, communicated less freely with the north lagoon than at present, for a submarine ridge runs out from Spanish Point—the tip of the thumb—to Ireland Island. At several points this ridge is awash at low tide.

Through the greater part of the main island there are three parallel roads (map 3): one—known as the middle road—runs in a general way along the ridge; the others—known as north and south roads—run along the north and south shores. The north and middle roads meet at the Flatts, and nearly all the travel between the only two cities, Hamilton and St. George's, passes over the bridge which crosses the gorge between the Inlet and Harrington Sound.

The houses of Bermuda are, almost without exception, made of the limestone rock which everywhere abounds. This is cut into blocks a foot or more in length, eight or ten inches wide and of different thicknesses. Even the roof is made of thin overlapping slabs of the same rock supported by slats that rest on wooden rafters. The houses, roof and wall, are whitewashed at frequent intervals, usually twice a year. The rain that falls on the roofs is carefully collected in covered cisterns, for it is the only source of fresh water in the islands, since there are no streams, and most of the rain pools last but a few hours even after the heaviest showers. In some localities barren tracts of land are denuded, the rock cut to a sloping surface and whitewashed to serve as a watershed for collecting rainwater in larger quantity than the roofs supply.

In addition to the garrisons and the marines there are on the islands about 18,000 people, two-thirds of whom are negroes, one-third whites, mostly of English extraction. There is a property qualification for voting; the proportion of whites to

MAP 3.



Map of the Middle Third of the Bermuda Islands. The position of the Laboratory is indicated by the lines "390" at the margins of the map.

390—

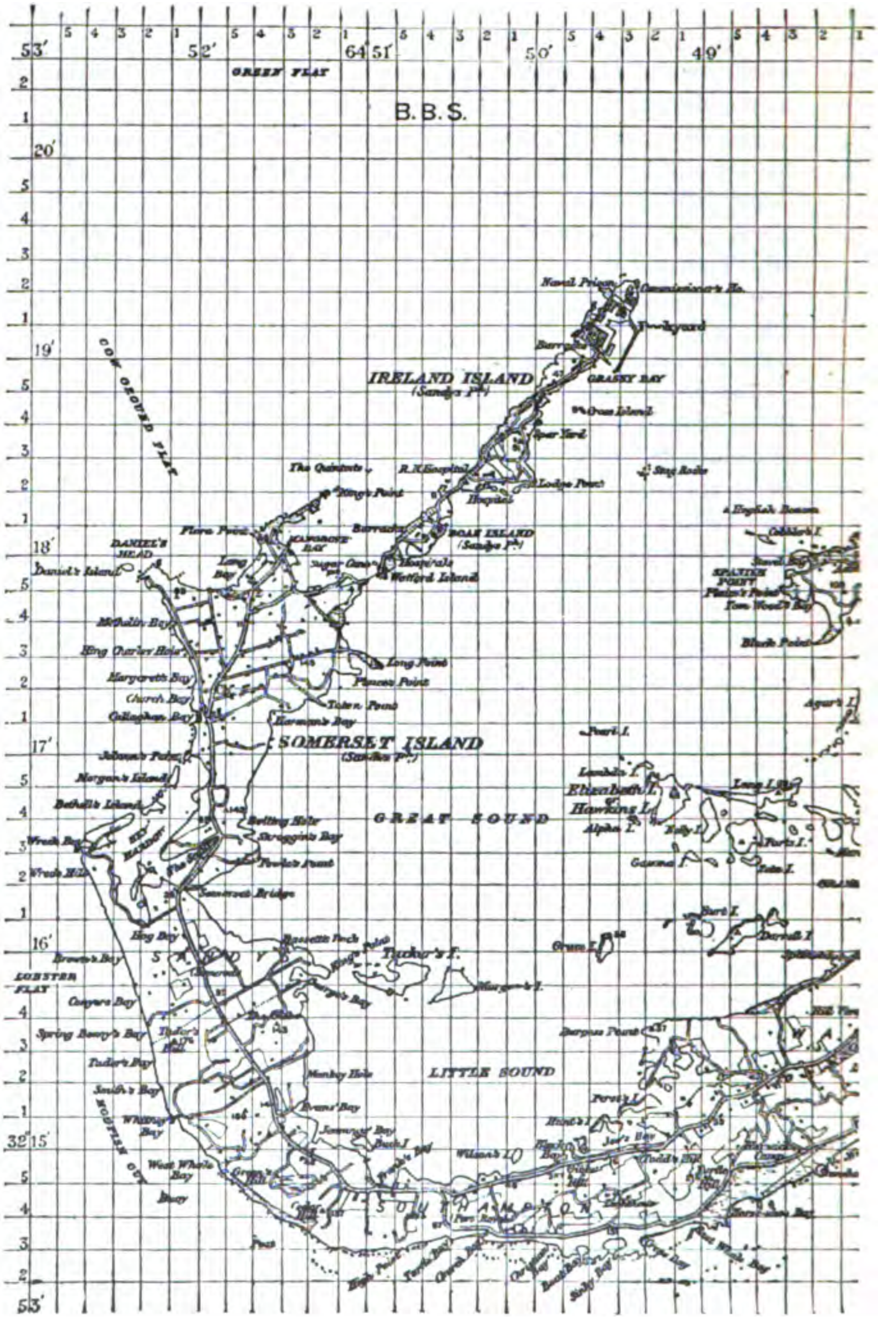
blacks on the voting list is two to one, the reverse of the ratio in population.

The cities, as I have said, are but two: the quaint town of St. George's, and the more modern town of Hamilton. St. George's is the more interesting because of its tortuous narrow streets, its high garden walls, and its ancient architecture, which suggest a mediæval European town (fig. 18). It was the seat of government until about a hundred years ago (1815), and retained for a long time after that an importance due largely to its fine harbor.

The visible land of Bermuda gives a very incomplete idea of the shape of the submarine plateau from which it rises. If the sea were to recede so that its surface was about thirty feet below its present level, we should have a great oval lagoon some twenty-five miles long and from twelve to fifteen wide, the rim of which would be made up in part of the present land area, and for the rest of a more or less continuous reef of coral-covered rocks a mile or so wide (map 1). The great central basin—the great northern lagoon, as I have called it—would have no considerable depth—seldom more than fifteen or twenty feet of water, and nowhere more than thirty—and would be studded with innumerable coral rocks and islands. Some of the deeper parts have special names, as Murray Anchorage and Grassy Bay, while the shallower parts are known as flats—Brackish Pond Flats, Bailey's Bay Flats, etc. The passages through this rim would be only three: Hog-fish Cut, Chub Cut, and the Narrows or Ship Channel. The slope of the sea bottom outside the rim is rather abrupt on the southeast side of the oval, less so on the northwest side, and least of all at the ends, as the position of the hundred-fathom line shows. Beyond the hundred-fathom line the bottom slopes even more rapidly to a depth of 1,200, 1,500 or even in places to 2,000 fathoms. These depths are reached at from two to five miles beyond the hundred-fathom line.

Rising from the floor of the sea some ten or twelve miles to the southwest of this oval plateau is another much smaller one, which would still be some 150 or 200 feet under the surface were the sea to recede, as we have imagined, thirty feet. This is known as the Challenger Bank.

MAP 4.



Map of the Southwestern Third of the Bermuda Islands.

Ten miles beyond this is another similar plateau of about the same size and height, called the Argus Bank. These two banks are in reality a part—two detached peaks, as it were—of the great submarine mountain of which the Bermuda Islands are the visible summit. For while the floor of the ocean sinks within five miles to about 1,500 fathoms, these plateaus are separated from each other and from the Bermuda plateau by less than half that depth.

The present land area of all the Bermuda Islands is composed of calcareous rock which varies from a loose sand to a firm, hard, semi-crystalline limestone that resounds to the blow of the hammer. What underlies this, no one yet knows. The deepest excavations—those for the new Navy Yard docks at Ireland Island—have not disclosed any other kind of rock. The numerous deep cuts for roads (fig. 19) and the quarries which are met with in all parts of the islands tell the same story. The rocks are composed of wind-blown calcareous sand. This sand, contrary to what was formerly supposed, is not composed of broken down corals. These are present only in small proportion, the chief constituents being fragments of shells, serpula tubes, and corallines. There are no such stratified subaqueous rocks as are found in this country, but everywhere the cut edges of the rock show the peculiar sinuous lines that characterize the stratification of drifting sands. The most, if not all, of the harder rocks are doubtless the result of the action of water and air on these æolian masses. At almost every point where the action of the sea is traceable it has resulted either in cementing together the layers of these æolian rocks till all evidence of stratification is lost, or else its mechanical effect has been more immediate than its chemical, and the rock has crumbled into its constituent grains and has become once more a sandy beach, in turn yielding up its substance to build the present sand dunes of the coast, which have the same æolian structure as their predecessors.

The mechanical action of the sea operating on the already hardened rocks has left them carved in the most fantastic shapes (figs. 2, 21) and with edges so sharp that it is almost impossible to walk upon them. In many places they are honey-combed through the action of water, and subterranean passages connect inland waters with the sea. Caves, too, sometimes of considerable extent, are found at various places, especially in the northern part of the islands, about Castle Harbor and Harrington Sound. The floors of these caves are in some places below sea-level, and since there is a free communication with the sea, deep pools of sea-water are not uncommon in them. The water is so clear and unruffled that the incautious visitor is liable to walk into the pools unawares, even after being especially cautioned against it. The stalactite and stalagmite formations point to the solvent action of water as the cause of the caves. It is highly probable that many of the depressed areas of the land known as "sinks," as well as the sounds and harbors, are the result of the falling in of the roofs of caves. The "sinks" vary in area from a few square yards to many acres.

These depressions contain the peculiar reddish-brown earth that makes farming and gardening possible in the Bermudas. The richness of this soil and the favorable climate allow the farmer to keep the earth under constant cultivation and to procure several crops in the course of a year.

Although trees and shrubs in great variety are to be found in Bermuda, the most of them are not peculiar to the islands, but probably owe their origin to introduction by natural agencies from the West Indies and the United States before historic times, while many are known to have been introduced by man, and not a few of these within comparatively recent times. The Bermuda cedar (Juniperus bermudiana) may be indigenous, though fifty years ago it was also found in the Blue Mountains of Jamaica. The palms—a dozen species of which are said to be growing in the islands—and the palmettos, are the most noticeable growths to attract the eye of the northerner. The royal palm (fig. 17) surpasses all others both in height and in beauty, but the cocoanut palm (fig. 12) is a worthy second, and many specimens of it are striking features of the landscape. In Queen Street, Hamilton, one drives beneath the sprawling branches of what we call a "rubber plant" when it grows in pots in our conservatories. Here its branches have a spread of a hundred feet or so. On entering the Public Garden at St. George's, where many interesting exotics are found, one is confronted by a stately screw pine of most symmetrical form, twenty or thirty feet high, and in the Agricultural Gardens near Hamilton another Pandanus of less graceful form but greater breadth is seen. Our common deciduous trees, however—the maples, beeches, birches, and oaks—are entirely wanting. In a private garden that contained many interesting trees and shrubs from various parts of the world I was shown as one of the greatest of curiosities a sickly specimen of one of our oaks. Even with the utmost care and attention these trees cannot be made to flourish in Bermuda; but oleanders have been introduced and flourish almost beyond belief. They are often used as hedge rows and grow to a height of 20 or 25 feet. A great variety of tints from deep scarlet—almost crimson—to pure white are to be seen. From May to September they enliven the face of the land with their brilliant colors, which occur in such masses that they are the admiration of all who see them. On the bleak north shores the tamarisk has been planted as a break against wind and salt-water. Though not an especially graceful shrub, the soft green of its fine-cut foliage makes a pleasant impression on the eye, and it enjoys the great practical advantage of being about the only kind of verdure that can really thrive in the presence of the abundant salt spray which the prevailing winds drive in upon the land.

The fiddle-wood tree (Citharexylum quadrangulare) is today the commonest of the deciduous trees in Bermuda, but the first tree of this species on the islands—the one from which all the others are said to have come—was imported as recently as 1830, and is still standing. The pride of India (Melia azedarach) is a rather scraggy, forlorn looking tree in midsummer, and one wonders why it is so much cultivated; but in early spring, before the leaves are out, it puts forth a profusion of pink flowers that makes it a great favorite with the Bermudians. It seems as though Bermuda must be the home of the genus Hibiscus, so many species are met with. In midsummer their blossoms exhibit some remarkably gorgeous colors. Still, the most superb of all the ornamental trees and shrubs to be seen in Bermuda is the Poinciana regia, a native of Madagascar, a tree with spreading branches clothed in the most pleasing green and decked with beautiful clusters of brilliant red blossoms.

The land animals of Bermuda, with the exception of insects and mollusks, are remarkably few, and of these the most are probably not natives of the islands any more than are the majority of the phænogamic plants.

Except for domesticated animals, mammals are numerous neither in species nor individuals. The most interesting one is doubtless the Wood Rat (Mus tectorum), which lives in trees and is now nearly extinct. This was at one time a dreaded scourge to the early settlers. Nearly 300 years ago (1619) Governor Butler, writing of the timely arrival of a so-called runaway frigate that brought food and thus averted impending famine, said: "But howsoever this runne away frigate brought with her a timely and acceptable sacrifice of her meale ; yet the companions of her meale, numbers of ratts (which wer the first that the ilands ever sawe), being received with-all and on a soudaine multiplyinge themselves by an infinite increase (for ther is noe place in the world so proper for them), within the space of one only yeare they became so terrible to the poore inhabitants, as that (like one of Pharaoths plagues) the whole plantation was almost utterly subverted therby; and so farr gone it was at last, that it proved Captaine Tucker's masterpiece all his time (which was not long after) to devise trapps and stratagems to conquer and destroye them, though indeed all of them proved to noe purpose (as you shall see hereafter) untill afterwards, one moneth of cold and wett weather did the deed." It is by no means certain, however, that these rats had not long existed on the islands, even though an earlier writer, Silvanus Jourdan, says (1610): "The countrey (foreasmuch as I could finde myself, or heare by others) affords no venimous creature or so much as a Rat or a mouse, or any other thing unwholesome."

Whales, which were once of some commercial importance to Bermuda, are so rare that they are no longer hunted, and the "whale-houses," of which there were recently half a dozen in existence, are but relics of an industry that has practically ceased.

The greater part of the 150 or more birds mentioned by Major Wedderburn (Jones: " The Naturalist in Bermuda"?), as found in the Bermudas, are migrants. The most conspicuous and interesting of them is the Tropic or Boatswain bird (fig. 16), which still continues to nest here, usually on the more remote and inaccessible islands.

The only representative of the Amphibia is the great Surinam toad (Bufo agua), which was introduced into Bermuda some twenty-five or thirty years ago by Captain Nathaniel Vesey to combat insect pests. I was fortunate enough during my first visit to Bermuda to find several of these toads spawning on the morning of April 22. There had been a heavy shower during the preceding night, which had resulted in temporary pools of fresh water in a few places, and it was in one of these pools near Spittal Pond that a half dozen or more pairs were found. A quantity of the spawn was secured and a series of eggs preserved.

Reptiles have at present very few representatives. There are no snakes, and the possible importation of them is carefully guarded against. The only land reptile is the Bermuda lizard (Eumices longirostris), which is not found elsewhere and is probably indigenous. Of turtles four species, none of which are peculiar to Bermuda, are known to frequent the islands—the green turtle (Chelonia mydas), the hawkbill (Eretmochelys imbricata), the loggerhead (Thalassochelys caouana) and the trunk or leather turtle (Sphargis coriacea). The green turtle is still caught in nets in small numbers, but the others are found only occasionally. From the accounts of several of the early writers on Bermuda it is evident that some of the turtles (perhaps the green turtle) were once very abundant. Sylvanus Jourdan, writing of the shipwreck of Sir George Somers in 1609, says: "There are also great store of Tortoises (which some call turtles), and those so great, that I have seene a bushell of egges in one of their bellies, which are sweeter than any Henne egge: and the Tortoise itselfe is all very good meate, and yieldeth great store of oyle, which is as sweete as any butter: and one of them will suffice fifty men a meale at least: and of these hath beene taken great store, with two boates at the least forty in one day. . . . We carried with vs also a good portion of Tortoise oyle, which either for frying or baking did vs very great pleasure, it being very sweete nourishing and wholesome." An early account of their egg-laying, by Peter Martyr, is given in these words: "At such time as the heate of Nature moueth them to generation, they come forthe of the Sea, and making a deepe pit in the sand, they lay three or foure hundred Egges therein: when they haue thus emptied their bag of Conception, they put as much of the same againe into the Pit as may satisfie to couer their Egges, and so resorte againe vnto the Sea, nothing carefull of their succession. At the day appointed of Nature to the procreation of these creatures there creepeth out a multitude of Tortoyses, as it were Pismyers out of an anthill, and this only by the heate of the Sunne, without any helpe of their Parents: their Egges are as big as Geese Egges, and themselues growne to perfection, bigger than great round Targets."

It is, however, the richness of the life in the sea, in marked contrast to the paucity of that on land, which is the chief source of attraction to the zoölogist. If the gardens on the land require much attention and are the reflection of man's assiduity in transplanting the products of one country to the soil of another, the gardens of the sea demand no such care, and man has had little or nothing to do with shaping the wonderful display of marine life that carpets the floors of the broad lagoons and the reefs of the Bermuda plateau.

Before speaking about the life in the seas, however, I wish to say a few words about the Bermuda Marine Laboratory. Not very long after my conversations with President Eliot, and when I was considering ways and means of providing an opportunity for students to work at Bermuda, I had the good fortune to make the acquaintance of Professor Bristol, and hear from him for the first time a glowing account of his experiences of several years, and his plans and hopes regarding a somewhat similar undertaking. Our aims had so much in common that co-operation seemed desirable to both of us, and we at length agreed to undertake, with the aid of the Bermuda Natural History Society, to equip and manage a provisional laboratory, which might serve till such time as the Colonial Government should be able to put at the disposal of biologists a permanent station. Chiefly through the enthusiastic interest of Dr. Bristol, in co-operation with the Bermuda Natural History Society, the Colonial Government had been led to entertain the idea of establishing a public aquarium for the enlightenment and amusement of people resident in the islands as well as the tourists, and in connection with it a marine laboratory for biological investigations. A Joint Committee of the Legislative Council and the House of Assembly, consisting of Sir S. Brownlow Gray, Chief Justice, Hon. Eyre Hutson, Colonial Secretary, and assemblymen J. H. Trimingham, Nathaniel Vesey, and A. Gosling, was appointed to consider the advisability of establishing such a station, and in due time reported favorably on the undertaking. The Governor, Lieut.-General Geary, at the suggestion of the Committee, entered into correspondence with many institutions and individuals both in Europe and America with a view to ascertaining their opinions as to the desirability of establishing such a station and the possibility of their co-operation. The replies were all favorable, and a certain amount of support was promised. Early in 1903 Professor Bristol and I were invited by the Natural History Society to visit Bermuda for the purpose of looking into the conditions and giving advice with regard to the general plan and certain matters of detail. This we did towards the end of April. Upon our return, and after the money necessary for the undertaking had been secured, we issued to biologists in the name of the Bermuda Natural History Society and the Universities which we represented an invitation to share for six weeks in the privileges of a temporary biological station at the Flatts, Bermuda. The generosity of the Natural History Society and the liberality of our friends allowed us to provide ample means for collecting and all the requisites for laboratory work, except that we had no running water in the laboratory. The building, however, was only a short distance from the sea, so that this deficiency was not very serious.

Through the favorable terms for transportation secured from the Quebec Steamship Co., and for board and lodging at the Hotel "Frascati," it was possible to make the cost of staying six weeks at the station, together with transportation from New York and back, only one hundred dollars. Thirty-seven persons availed themselves of this opportunity, and of these thirty-three were engaged in the study of zoölogy or botany, four being companions of one or another of those who were working in the laboratory. Of these thirty-seven persons about a dozen sailed from New York on June 20, the remainder two weeks later. Arriving in Hamilton, the party was met on board the steamer and welcomed by Archdeacon Tucker, President of the Bermuda Natural History Society, U. S. Consul W. Maxwell Greene, Vice-President, F. Goodwin Gosling, Honorary Secretary, and other members of the Society. A carriage ride of four miles over Mt. Langton and along the north road—from which one gets magnificent views of the great north lagoon and its ever-changing appearance—brought the party to the Flatts and the hotel. The Flatts village (fig. 4) centers at the cross-roads near the bridge (figs. 30, 31) which spans the narrow passage from the Inlet into Harrington Sound. It contains the hotel, the post-office, a half-dozen shops, and one or two scores of dwellings, which range in size and attractiveness from "Palmetto Grove," the home of Archdeacon Tucker, to the twenty-foot cottage of the unambitious colored family. On nearing the Flatts the north road runs along the hillside that rises to the south of the Inlet, gradually descending to sea level at the corners, where it meets the middle road. The cottages are scattered over this hillside, which looks out on Harrington Sound (fig. 30) and affords at many spots beautiful views of that land-locked sea and the wooded heights beyond. The hotel (figs. 13, 31) is located on a low projection of land that makes out into the Inlet from its south shore and commands on one side a view of the sea (fig. 9) on the other a view into Harrington Sound. It consists of half a dozen buildings; two of stone (one built as a residence many years ago) placed gable to gable and facing the water; a much newer wooden structure, which, with its broad piazza, projects out over the clear waters of the Inlet; the kitchens and a store-house behind the older buildings, and, lastly, a new stone building some forty feet square, located back of the wooden one, between it and the public road. This building we rented for a laboratory (fig. 8). It had been divided up by light partitions into several rooms, and proved to be fairly well adapted to our needs. The laboratories were furnished with substantial work tables having ebonized tops and banks of drawers. A library of specially selected books and pamphlets from the libraries of the Museum of Comparative Zoölogy, the Boston Society of Natural History, and the writer, several hunderd in number, were arranged in the largest work room. An ample supply of glassware, reagents and preservatives, dissecting lenses, microtomes, paraffin imbedding devices, and all the other usual equipment of a zoölogical laboratory were provided, as well as the necessary appliances for collecting, such as dredges, nets, seines, tubs, buckets, sieves, water glasses, *et cetera*, so that few wants were felt in this direction by any of the party. The number of students was, however, so large that the laboratory building was inadequate for the accommodation of all. When the second party arrived, therefore, a large ground-floor room in one of the stone buildings of the hotel was fitted up with portable tables for those who had less need of appliances for microscopic work.

Very satisfactory means of transportation to collecting grounds, both by land and by water, were provided. For places not readily accessible by boats, wagonettes and carriages were furnished, and those who collected land plants made much use of them. Several persons had brought with them their bicycles, and thus were less dependent on the organized parties. Regular excursions were arranged for nearly every day except Sundays; frequently two in a day, and sometimes two by sea and one by land. As far as practicable, shore collecting and coral "nipping" on the reefs were planned for the low-tide hours of the day and dredging for other times.

One of the places most frequently visited by land conveyance was Hungry Bay, on the south shore nearly opposite Hamilton. The entrance to the bay is narrow and rocky, yet a great variety of animals are blown in by the southerly winds and the place has thus become a rich collecting ground. The loose and porous rocks just inside the entrance on either shore afford hiding places for great numbers of worms and other invertebrates. Upon turning over these rocks the bottom seems alive with creatures of many kinds. Only half the booty is seen, however, unless the rocks are broken into fragments. Thus are set free boring mollusks, annelids, and many other forms that find protection, or a lair, in the holes and tortuous passages of this porous, honey-combed limestone.

In many places the floor of the shallower parts of the bay is covered by a large tubularian hydroid, in others, where the current is stronger, by great yellowish or greenish patches of colonial actinians (Palythoa) belonging to the Zoanthidæ (fig. 27). The upper end of this bay is a swamp of mangroves (compare fig. 14), on the branches of which numbers of tree crabs (Goniopsis cruentatus) clamber about. To catch these creatures requires some skill, two persons usually succeeding better than one, for the crab when too closely pursued quickly drops to the ground, even from a height of 10 or 15 feet, and escapes into a burrow, unless a net is dexterously interposed during its descent. Along the edges of the tidal stream near the head of the bay are found in great numbers prawns that are so transparent as to escape observation until they move. They dart about with such swiftness that it is difficult to take them in the net.

When one cautiously approaches the edge of the cliffs that flank the entrance to the bay and looks down on the hard, wave-beaten rocks, he sees large numbers of crabs that take alarm at the least motion and scurry away to crevices, or scramble down into fairly deep water, where, with their sharp claws, they are able to cling to the rough rocks and make almost as good progress as in the air. On the platforms and in the niches of the rock between tide marks are congregated hundreds of chitons (Chiton marmoreus), whose shells give proof of the action of the waves, which are almost constantly dashing against them at high water.

In view of the possibility of the establishment of a permanent station, it seemed desirable to keep records of the places where various animals and plants were found. To this end each person was provided with a note-book, and to prevent duplication of locality numbers, certain locality numbers were assigned with each book. Whenever a party of individuals made collections together in a circumscribed area, as in dredging, or in shore collecting at particular spots, the same locality number was used by all. To enable future workers to find the precise localities mentioned, these places were designated by latitude and longitude. Fortunately for this plan there had been recently published an Ordinance-Survey map of the Bermudas on a scale of 880 feet to the inch, so that by ruling one of these maps with rectangles ten seconds square it was possible to indicate on the map the position of any locality to within a very few feet, as the position of the laboratory is shown on Map 3.

A card catalogue embracing the names of all the animals and plants arranged systematically will ultimately show, not only what organisms, both living and fossil, are to be met with in the islands and adjacent waters, but also the precise localities at which they have been found, and the conditions under which they live. To this will be added as rapidly as possible the periods of ovulation, etc., so that one may not waste time in searching in the wrong place or at the wrong time of year for the material one needs.

In the immediate vicinity of the laboratory—in the Inlet and in Harrington Sound—are found an abundant supply of many interesting animals. From the stone pier at the hotel are to be seen great numbers of brightly colored fishes—the yellow-banded Sergeant Majors (Abudefduf saxatilis), Sea Squirrels (Holocentrus ascensionis), so called on account of the bigness of the their eyes, Angel fishes (Angelichthys ciliaris), Four Eyes (Chætodon bimaculatus), and many others. The large eye-spots of the Four Eyes at the tail end of the body evidently afford protection by misleading their enemies into the belief that they will attempt to escape in a direction opposite that in which they actually swim. Schools of blue fry and other small fishes pursued by their enemies make a flash in the sunlight as they leap from the water and a sound like the patter of rain as they descend. Small shoals of White Grunt (Bathystoma), that so closely resemble the sandy bottom as to be almost invisible, are slowly patrolling along the beach and often attract one's attention only when their presence causes a commotion among their prospective victims.

The water is so clear that the bottom at a depth of fifteen or twenty feet is seen as distinctly as it would be beneath as many inches of our northern waters. Along the sandy stretches of the Inlet, where the current is not too strong, are numerous dark sea-urchins (Toxopneustes variegatus), which have the interesting habit of covering themselves with empty shells, sea weeds, or any loose available fragments. Just what sort of protection these screens afford, is not quite apparent. To the observer looking from above they are scarcely less conspicuous than when unadorned. Their specific form and characteristic color, it is true, are masked, and possibly this is enough to subserve some useful purpose. By digging a few inches deep in the sand at the right spot one brings up another echinoid, the sand-dollar (Mellita sexforis). Scattered over the bottom are the apparently motionless but conspicuous sea-cucumbers, which the natives call sea-puddings—the Stichopus diaboli, and S. xanthomela of Heilprin. These often attain the length of a foot or more and leave behind, to mark the track of their slow progress, a cord or ridge of sand that has been deprived of its nutritive material in passing through their intestinal tract. These are abundant on many sandy bottoms ; other holothurians are less widely distributed. In the shallower parts of the Inlet, which are laid bare at low tide, are the burrows of many annelids and other worms. Where the channel is rocky and the water moves with greater velocity the bottom is often gorgeously painted with patches of bright-colored corallines and encrusting sponges. Opposite the hotel an artificial channel, cut through the narrow neck of land that separates the Inlet from Harrington Sound, is of this nature and affords a rich collecting ground for many invertebrates. With a row boat and a good water-glass one may study with delight the shores of Harrington Sound and its numerous coves and get beautiful views of the delicate shade-corals (Agaricia fragilis, fig. 28), the many kinds of sea anemones (figs. 24–26), and the sponges which abound there. Collecting is easy, and the variety of life great. Occasionally the long "whips" of the Bermuda lobster (Panuliris argus) are seen projecting out of some crevice in the rock, as he lies in wait for his prey. If less palatable than our American lobster, the Bermudian has a more graceful form and a much handsomer livery (fig. 22).

In addition to a thirty-foot sail boat, with its glass-bottomed fish-well, such as the native fishermen use, the Station was furnished in the summer of 1903 with a steam launch (fig. 7) some 35 feet long—the "Minnow." For three-fourths of her length she had a light wooden deck and side curtains, which could be lowered to keep out sun, rain, or spray. Her pilot house was low, but roomy, and served as a forward cabin as well as wheel house. In this launch almost daily excursions were made to various parts of the archipelago, according as the conditions of wind and tide favored this or that locality. For all purposes except that of dredging she was well suited to our needs, for, being of light draught, she could be used about the shoals and flats with safety and ease.

I recall with pleasure not only my own fascination, but also the expressions of delight which involuntarily came from the lips of all who, with water-glass in hand, peered down into the fairy-like gardens of the sea, as we slowly drifted with the tide, or lay at anchor in the midst of one of the great coral patches that flourish over extensive areas of the north lagoon. I confess the pleasure was so great that the spirit of the collector was suppressed for the time being; it seemed sacrilege to touch with violent hands a picture that showed such harmony of form and color,—the waving plumes, the graceful branches of the gorgonias; sea fans in purple splendor; coral heads of gold and green; great splotches of colored sponges encrusting the rocks; the soft sea weeds; here and there deep channels with nothing but the clear water and the white sand beneath it; and in and out among this maze of growing things, the graceful, noiseless fishes in such array of colors as is scarcely credible, much less describable. I believe it may be truly said that one who has never seen such a tropical sea-garden cannot have the remotest idea of its charms. There was only one consideration that could reconcile me to the wanton work of collecting these beautiful things and robbing them of all their native charm; that was the fact that, work as diligently as we might, we could not deface one in a thousand of these fascinating spots. I think there is no other single experience I would willingly exchange for this, and yet I recall one other, ot a somewhat different nature, that made a strong impression on me. As three of us were out one afternoon off the south shore beyond the reefs fishing in about sixty fathoms, there came floating past with the tide a school of jelly fishes, the common Aurelia. I have before seen Aurelia almost cover the surface of the sea, but never before had I been able to look down, as then, and see them in the depths of the sea. They were seemingly without end, a vast procession, smaller and smaller the deeper one gazed, until they seemed mere specks, such was the clearness of the water.

For use in dredging a larger steamer (fig. 11), the "Intrepid," was for a part of the time at our command in place of the "Minnow." This steamer was provided with a boom in front of the pilot house, which much facilitated dredging operations, and the forward deck was a convenient place for inspecting the dredgings, assorting tows, etc. This was the steamer that had been employed by Mr. Agassiz during his explorations in 1894. With her we made, besides other excursions, several trips to North Rocks (fig. 5)—three sole survivors of the land mass that doubtless extended in previous times along the northern border of the lagoon, as the present land area now does along its southern rim. It is only on the calmest days and at lowest tide that one may safely land on the plateau from which these three pinnacles, called North Rocks, arise. The steamer can approach within a half or a quarter of a mile and then must anchor, while in rowboats the collectors make their way to this sea-washed platform. On the sea face the rock, which is an æolian limestone, is slightly raised above the general level of the floor, and is overgrown with nullipores and other corallines, as well as non-calcareous algæ; and here serpulas, millepores, and porites abound. Even at low tide this rocky platform is barely above water, and it is so honeycomed and porous that its surface is very irregular. The flatter portions are covered here and there with patches of the curious Zoanthidæ. There are innumerable pools and channels, all showing the greatest variety of color in the plant and animal life that clothe their sides and bottoms. Here, in the pools and passages, is a greater wealth and variety of life than can be found in an equal area elsewhere in all the Bermuda archipelago. Located on the very edge of the outer reef, where breakers are always running, save in perfectly calm weather, the conditions seem to be especially favorable for many of the marine organisms. Numerous small and brilliantly colored fishes dart about in the pools, and escape into the crevices of the rock as one attempts to scoop them up. The great black sea-urchin (Diadema setosum), bristling with slender spines, is firmly ensconced in niches in the rocky floor, and usually defies all attempts at removal. But by breaking away the rim of projecting rock this urchin may sometimes be dislodged. Unless great care is used, however, his spines, which are like needles, will penetrate the flesh, where they are sure to break off and become a source of great irritation if not promptly removed ; but they are so brittle that removal is not an easy matter. Crabs, both great and small, are everywhere, and the little hermits, with their molluscan shelters of various kinds and sizes, make a grotesque appearance as they scuttle away to cover.

One of the most novel sights that I saw in these tropical seas was viewed through a water-glass near North Rocks. A school of small fishes (Atherina) swimming in a nearly spherical mass ten or fifteen feet in diameter, seemed to be slowly revolving through the water as its individuals swam round and round in an almost solid mass. It was not at first apparent how the mass preserved such a constant form, but at length it was seen that a few individuals of another and larger species of fish were acting the part of the shepherd dog, and that the smaller fishes were actually being herded—a flock of submarine sheep. Nor do the herding fishes prey upon their flocks. The explanation is interesting. Three kinds of fishes are involved in this association. The herders accompany and "round up" the smaller fishes, so that other kinds of fish which are wont to prey upon them may, as they approach with murderous intent, fall victims to the herders.

Picturesque Castle Island, which still contains ruins of early fortifications, some of them possibly dating from the early part of the 17th century, once guarded the entrance from the sea through the channel of Castle Roads. From the floor of this channel the dredge brings up many interesting animals: the

"Flora," owned by Mr. Henry H. Barton, of this city. This launch was larger (about 45 feet over all) and in many ways better than the "Minnow." This year we were fortunate enough to find at several localities a near relative of Amphioxus, the interesting Asymmetron, which was discovered several years ago at the Bahamas by Prof. Andrews, of Johns Hopkins University. This was first recognized at Bermuda by Mr. Louis Mowbray, of St. George's, who was a member of the Station party. It is an interesting fact that, so far as our search extended, Amphioxus and Asymmetron do not inhabit the same sand banks. The Bermuda Asymmetron is much smaller than Amphioxus and much more expeditious in burrowing into the sand. Amphioxus is remarkably quick in its movements, but Asymmetron is quicker. The habits of these two primitive vertebrates, as well as the finer anatomy of their nervous systems, and the anatomy and physiology of other organs, were studied by members of the party this year, and will form the basis of special papers to be published later.

In conclusion, I wish to state that the Bermuda Government has decided to erect a permanent Aquarium and Biological Station at the Flatts, in accordance with the plans that I have already referred to, and has voted a sum of money (about $20,000) for the undertaking, and a smaller annual sum ($2,000) for its maintenance. It is expected that when the buildings are completed arrangements will be made to have the Station open for research throughout the year.

EXPLANATION OF FIGURES.

I am greatly indebted to Professor A. E. Verrill for the use of the cuts shown in Figures 14 to 29 inclusive, which are taken from the Transactions of the Connecticut Academy of Science and from his "The Burmuda Islands," New Haven, 1902, and "Zoölogy of the Bermudas," New Haven, 1903; also to Mr. A. Peniston for the use of Figures 30 and 31.

PLATE 1.

FIG. 1.—View of Hamilton from the Harbor. From a photograph by Phelps Gage.

2.—Water-worn rocks, south shore.

PLATE 2.

3.—Front Street, Hamilton; U. S. Consulate in the distance. Photo. by L. J. Cole.

4.—View of Flatts Village from window of Hotel Frascati. Photo. by A. M. Miller.

PLATE 3.

5.—North Rocks. From photograph by Phelps Gage.

6.—Residence surrounded by palmetto trees. Photo. by Phelps Gage.

PLATE 4.

7.—The "Minnow" starting on an excursion. Photo. by Albert Mann.

8.—The Laboratory, western face. Photo. by C. L. Bristol.

PLATE 5.

9.—View of "Wistowe" and the Inlet from the piazza of Hotel Frascati, looking toward the great north lagoon.

10.—Diminutive atolls ("boilers") in the foreground; reef in the distance.

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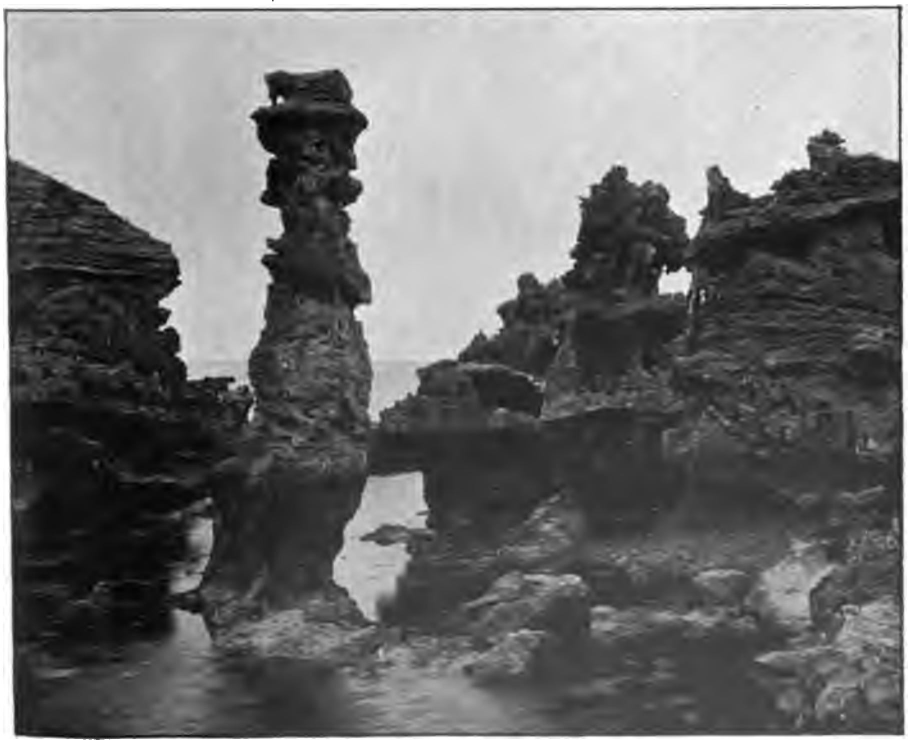

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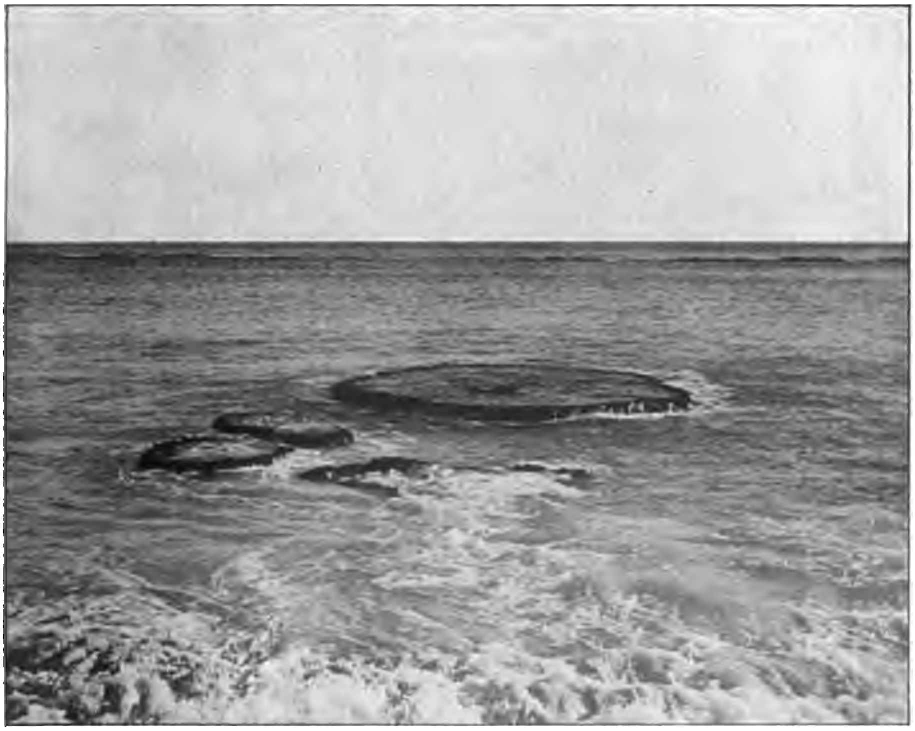

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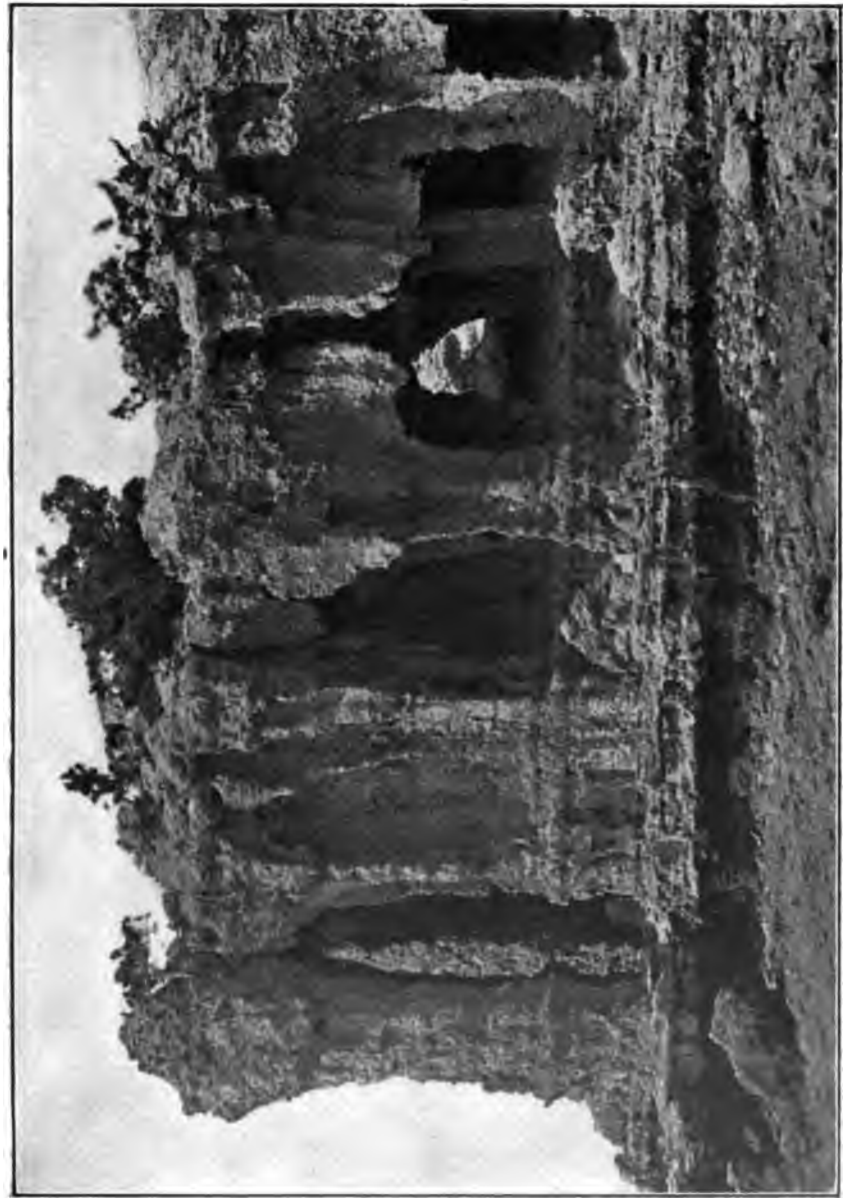
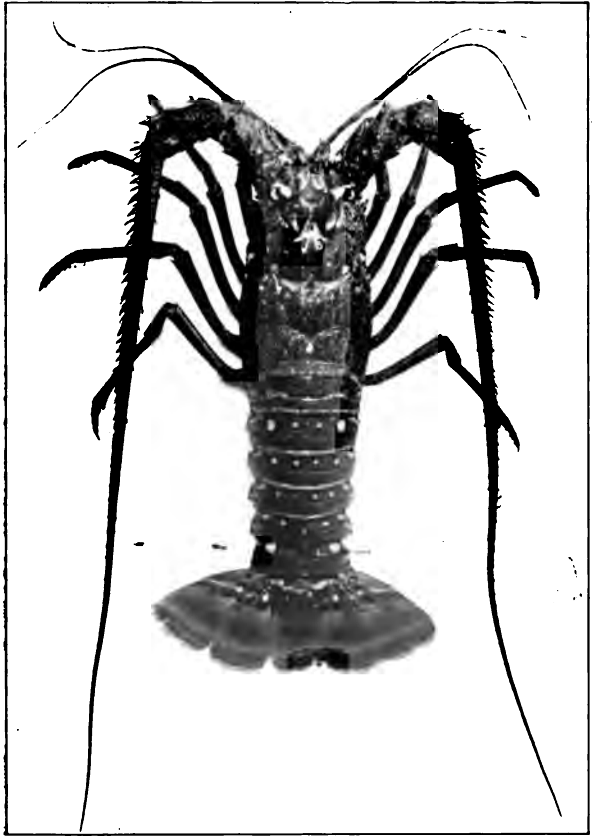
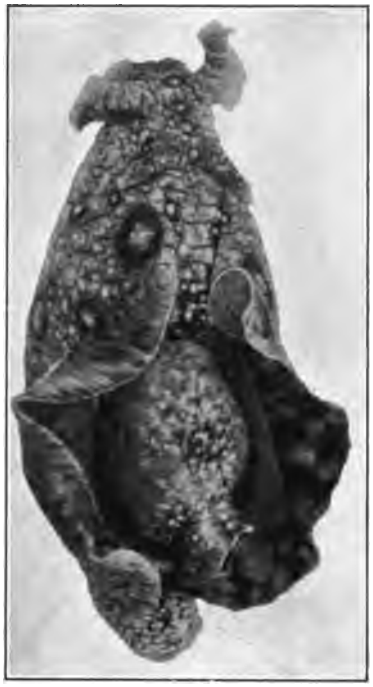
Plate II







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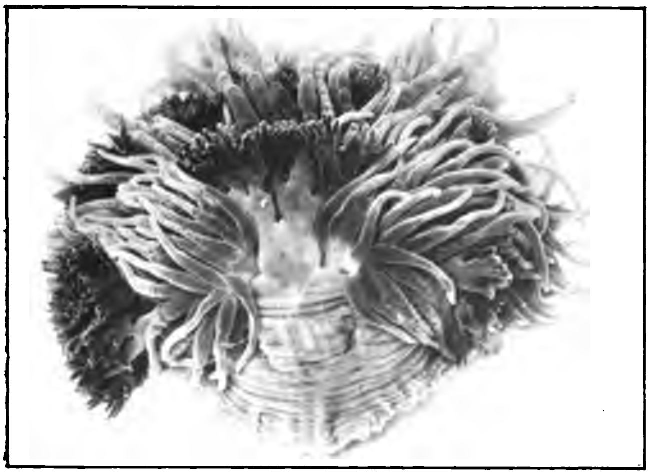

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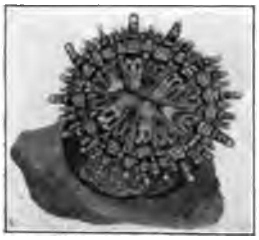

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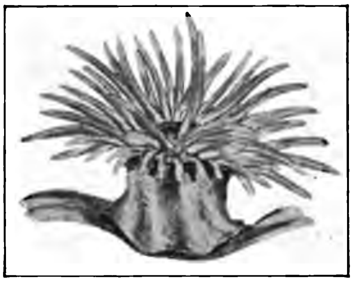

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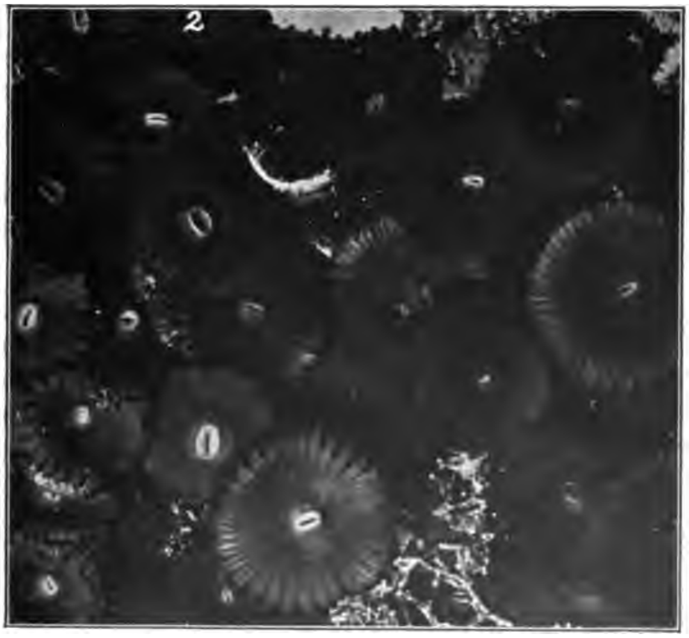

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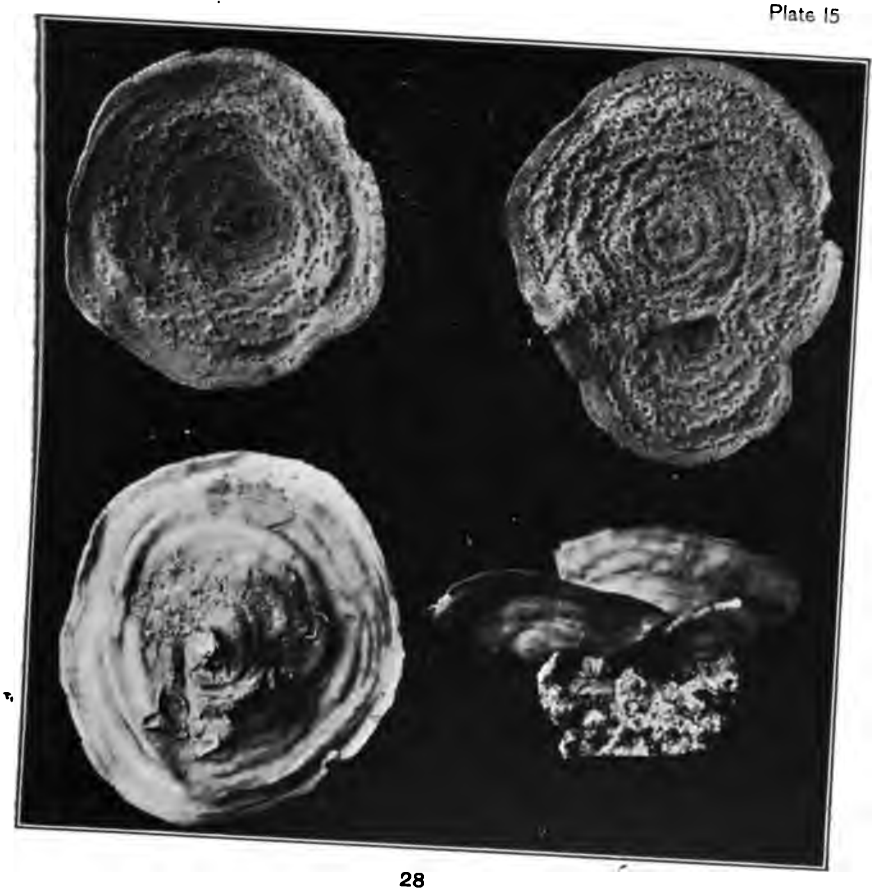

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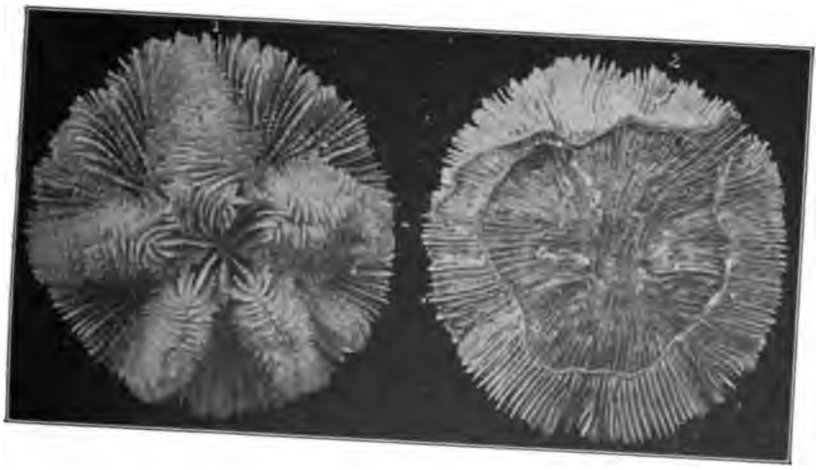

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59.7 (729.9)

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By Thomas Barbour.

With Four Plates.

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September, 1905.

No. 7.—*Notes on Bermudian Fishes.*[1] By THOMAS BARBOUR.

THE material which forms the basis for this paper belongs to the Museum of Comparative Zoölogy and is from several sources: first, a collection made by my brother, Mr. W. W. Barbour, and myself during parts of March and April, 1903; secondly, a large and rather complete collection made during part of June, July, and part of August, 1903, while I was attached to the Biological Station at Flatts, Bermuda; thirdly, a number of specimens in the collections of the Museum of Comparative Zoölogy, and finally, a series obtained by Professor Mark and collected at the Station during the summer of 1904. I here express my gratitude to Dr. Mark for his kindness in procuring a number of most interesting specimens, and thank Messrs. H. B. Bigelow, Owen Bryant, and J. T. Nichols, for their kind aid in collecting and preserving the largest collection. Finally, it is a pleasure to thank Mr. Samuel Garman of the Museum for the assistance he has giving me in making the identifications.

Before turning to a systematic consideration of the material in hand, a few words are necessary in explanation of the peculiar faunal conditions which obtain about the Bermuda Islands. In 1872 Dr. G. Brown Goode visited the Bermudas for several weeks (February to March), and made the first collections of any considerable size or value from this locality. He pointed out in his paper on the fishes (Goode '76²) the splendid opportunity here presented to the ichthyologist for the study of the effects which the ocean currents have had in providing Bermuda with a fish fauna. He called attention to the fact that almost all the more characteristic fishes of the West Indian regions, and also many fishes which are found in the Azores, Canaries, Madeira, Cape de Verde Islands, and even on the coasts of Southern Europe and Africa are represented in Bermudian waters. One of the most interesting examples of distribution probably due to ocean currents is the occurrence of *Synodus saurus*, a fish which, on account of its sluggish, bottom-loving disposition, one would consider unlikely to range far from home. The majority of the species derived from distant regions, are, as Goode¹ has pointed out, powerful and rapid swimmers. Few of the species which have been described as peculiar to Bermuda have remained so long. Both *Stolephorus choerostomus* and *Siphostoma jonesi* were once believed to be peculiar to Bermuda, but only a year or so ago the U. S. Fish Commission expedition to Porto Rico found both these species there. The Bermuda representatives were in all probability derived from the West Indian region. *Ulaema lefroyi* also is now known from many of the West Indies, and the Florida Keys.

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[1] Contributions from the Bermuda Biological Station for Research. No. 6.

The classic on the general Natural History of the Bermudas is Jones, Wedderburn, and Hurdis (**'59**); while more recently Verrill (**:02**) has published a most valuable and interesting volume dealing with the history, scenery, etc., of the island and on the faunistic changes due to man. In (**:01**) Verrill also published a paper dealing with the fauna; this contains a short article on the fishes. The birds and several groups of invertebrates have been treated in a volume by Jones and Goode (**'84**). An interesting popular account of the fish markets of Bermuda was published by Goode (**'76^b**) in "Forest and Stream." Günther (**'79**) has listed the species of fishes taken by the naturalists of H. M. S. Challenger near the islands.

In the present paper the notes on distribution are obtained partly from "The Fishes of North and Middle America," by Jordan and Everman, which I have found very valuable in this connection, and partly from specimens in the vast collections of the Museum of Comparative Zoölogy.

LEPTOCARDII.

BRANCHIOSTOMATIDAE.

Branchiostoma caribbaeum Sundeval. **The West Indian Lancelet.**

Verrill, **:01**, p. 55.
Goode, **'77**, p. 293 (*B. lubricum*).

Distribution. — Atlantic coast of North America to Rio Plata.

Found in all localities where the bottom is suitable. Very common on the sandy spit in Flatts Inlet, directly opposite the Hotel Frascati.

Asymmetron lucayanum Andrews. **Andrews's Lancelet.**

Mark, **:04**, p. 179.

Distribution. — Bahamas and Bermudas.

Taken in dredgings at a number of localities in different parts of the Bermudas.

PLAGIOSTOMI.

GALEIDAE.

Carcharhinus platyodon (Poey). Puppy Shark.

Verrill, :**01**, p. 55.

Distribution. — Coasts of Texas and Cuba.

Very common off the Challenger Banks and outside the reefs. Considered a fine food fish by the colored people. The only specimen preserved was identified by Mr. Garman as belonging to this species.

TELEOSTEI.

ANGUILLIDAE.

Anguilla chrisypa Raf. Eel.

A. bostoniensis (Le Sueur) Ayres. Goode, '**76**^{a}, p. 71.

Distribution. — Atlantic coast (ascending rivers); West Indies.

Said to be common in ditches in Devonshire Marshes. The specimens, seven in number, were all obtained in mud-holes near the mangrove swamp at Hungry Bay. I found four there in April, 1903, and three in July, 1903. The largest specimen was about 4 inches in length. The only water connection of this swamp was directly with the ocean, and as no eels have ever been taken off the shores of Bermuda, it puzzles me to know how such young eels got into the mangrove swamp. The Devonshire Marshes, so far as I could learn, have no connection with the ocean; the water there is only slightly brackish.

MURAENIDAE.

Lycodontis moringa (Cuv.) Spotted Moray.

Gymnothorax moringa (Cuv.) Goode. Goode, '**76**^{a}, p. 72.

Distribution. — West Indies; North coast of South America; St. Helena.

This species with the larger *L. funebris* (Ranzani) was quite common about all the reefs, particularly off the south shore, where many are taken by fishing from the rocks. The specimen before me was taken during the "Challenger Bank Expedition" — a three-days trip provided by Captain Meyer, of St. George's, for the members of the Biological Station about the first of August, 1903. The flesh is eaten by the negroes, who say that it is sugary-sweet, and very tender; I heard nothing of its being considered poisonous.

L. sanctae-helenae (Günther).

Distribution. — Tropical Atlantic; St. Helena.

A single example taken in 1904; compared with the preceding this species is rather rare.

OPHICHTHYIDAE.

Sphagebranchus anguiformis (Peters).

Distribution. — West Indian region.

A single example of this rare species was dredged in shallow water by Professor Mark on Aug. 6., 1904, at Station No. 468. It is without spots and is 5½ inches long. The head is contained 18 times in the length of the body. A second specimen of this species, which I may mention in this connection, was dredged by Messrs. G. M. Allen, Owen Bryant and myself while on our Northern Bahama Expedition in July, 1904. It is far larger, being of the same proportions and 12½ inches long. It was dredged in 14 fms. in Whale Cay Channel off the Island of Abaco, Bahamas.

ALBULIDAE.

Albula vulpes (Linné). Bone fish.

Distribution. — Tropical seas, almost universally distributed.

D. 15; A. 8.

The species is rare at Bermuda; I have examined only a single specimen taken there. (M. C. Z. No. 18,088.)

CLUPEIDAE.

Sardinella anchovia Cuv. & Val. Anchovy.

Goode, '76ᵃ, p. 69.

Distribution. — West Indies, N. Coast of South America.

D. 16; A. 16.

Large schools of this clupeoid were seined regularly in Hamilton Harbor and Flatts Inlet for bait. They appeared to run up into shoal water at about sunrise or sundown.

S. macrophthalma (Ranzani). Pilchard.

Harengula macrophthalma (Ranzani). Goode, '76ᵃ, p. 69.

Distribution. — West Indies, coast of Brazil.

D. 17; A. 18. Sc. 40; 12.

We took only two specimens of this species. Mr. H. B. Bigelow and myself each took one about 11 o'clock one very warm evening in August in Flatts Inlet on a hook baited with strips of *Bathystoma.* A dark lantern turned toward the water showed a considerable number of what appeared to be the same species swimming about; no more were seen afterward. They are said to be rather common in winter.

Opisthonema oglinum (Le Sueur). Herring.

O. thrissa (L.) Goode, '76ᵃ, p. 69.

Distribution. — West Indies, common on coasts of Florida, Georgia, and the Carolinas, occasionally much further northward.

D. 19 ; A. 24.

I have about 100 specimens of this common tropical herring, varying in size from one to five inches. They appeared erratically in great schools.

ENGRAULIDAE.

Stolephorus choerostomus (Goode). Hog-mouth Fry.

Engraulis choerostomus Goode. Goode, '74, p. 380; and '76ᵃ, p. 70.
Jordan & Evermann, '96–00, vol. 1 (1896), p. 444.

Distribution. — Bermuda and Porto Rico.

D. 13 or 14; A. 23.

This species was not at all common during July, but in August immense quantities were seined for bait in Bailey's Bay and Flatts Inlet.

SYNODONTIDAE.

Synodus saurus (Linné). Snake fish.

S. lacerta (Valenciennes) Goode. Goode, '76ᵃ, p. 68.
Jordan & Evermann, '96–00, vol. 1 (1896), p. 537.

Distribution. — Atlantic coast of Southern Europe ; Bermuda.

D. 12; A. 12.

One of the two specimens taken jumped into a rowboat at Flatts Inlet; they frequently rise three feet from the water in the upward dash after their prey. The second specimen was taken from the fish pot of a Portuguese at Cooper's Island by Messrs. Nichols and Bryant.

We had many opportunities to watch their habits as they lay on the white shell and coral sand in the Flatts Inlet. They changed color remarkably and mimicked their surroundings very closely indeed. They would wait until their food, usually a small fish, was directly over them, and then rise with great speed, and seize it from below.

ESOCIDAE.

Tylosurus raphidoma (Ranzani).

Distribution. — West Indies; coasts of Florida and Brazil.

D. 23; A. 22.

This species has not, I believe, been found at Bermuda before. One small specimen (4½" lg.) was taken with a fine seine in Flatts Inlet. It showed none of the silvery coloring of the adults, but was covered with stellate chromatophores.

T. acus (Lacépède). Hound.

Distribution. — West Indies, occasionally northward and in the Mediterranean Sea.

D. 23; A. 21.

This species was present in great numbers in most of the inlets and bays about the islands. We obtained a number of specimens on hooks baited with *Sardinella* or *Stolephorus*. These fishes play havoc with the useful bait fishes, killing numbers which they do not eat. They all contained parasitic worms in the trunk musculature.

HEMIRAMPHIDAE.

Hyporhamphus unifasciatus (Ranzani). Needle fish, Gar fish.

Distribution. — Southern Florida, Panama, and Brazil.

D. 12; A. 15.

Specimens were taken with seine at low tide in the Flatts Inlet. They were quite common, but did not appear as regularly or in as large numbers as did *Tylosurus acus*.

Hemiramphus brasiliensis (Linné).

H. pleii (Cuv. & Val.) Goode. Goode, '76^a, p. 64.

Distribution. — The West Indian region.

D. 14; A. 12.

One badly damaged specimen, apparently of this species, is in the collection of the M. C. Z. No. 8,774, taken by Captain Hamilton at Bermuda about 1870.

EXOCOETIDAE.

Exonautes esiliens (Müller). Flying fish.

Exocoetus exiliens Gmelin. Goode, '76^a, p. 64.

Distribution. — Pelagic.

D. 12–13; A. 12; P. 18; V. 6; C. 21.

One young specimen of what appears to be this species was taken from *Sargassum* off the Challenger Banks and thirteen young examples were taken in the tow net, July 7, at 9 p. m., wind east, in Flatts Inlet. No adult flying-fishes were seen close to shore at any time, and only very few inside the outer reefs. Hundreds of flying fishes, however, were seen from the steamer from forty to sixty miles off shore.

FISTULARIIDAE.

Fistularia tabacaria Linné.

Goode, '76^a, p. 27.

Fistularia serrata Goode, '76^a, p. 75.

Distribution. — West Indies, straying northward.

D. 14; A. 13.

One specimen of this curious species was taken by Mr. L. Mowbray off St. George's and was kindly obtained from him by Prof. E. L. Mark for examination.

SYNGNATHIDAE.

Siphostoma jonesi (Günther).

Jordan & Evermann, '96–00, vol. 1 (1896), p. 768.
Syngnathus jonesi Günther, '74, p. 455. Goode, '76ᵃ, p. 27.

Distribution. — Bermuda and Porto Rico.

Mr. O. Bryant obtained a single specimen of this species under a rock at Hungry Bay; and a second specimen has recently been handed me by Professor Mark; it was taken during July, 1904.

S. pelagicum (Osbeck).

Syngnathus pelagicus Osbeck. Goode, 76ᵃ, p. 27.

Distribution. — Tropical Atlantic and Mediterranean.

About a dozen specimens were obtained in *Sargassum* and by the dredge in from 6–12 fm. Several very large specimens were taken during July, 1904.

S. mackayi Swain & Meek.

Distribution. — S. Florida to Yucatan.

One small specimen was taken from the dredge in Castle Harbor. This is the first time the species has been reported from Bermuda.

S. dendriticum, sp. nov.

(Plate 1.)

Type, (M. C. Z. No. 29,057) a single specimen dredged in about 7 fms. off Ireland Island, Bermudas, July, 1904.

Rings 14 + 39. Dorsal 16, just over vent on rings 1–4.

Snout about twice in distance to base of pectoral. Tail longer than body. Anal fin vestigial; composed of two rays on ring 2. Color brown with irregular blotches and darker marblings. A number of peculiar filamentous appendages; many of these have probably been torn off, as this specimen was taken in the dredge with a considerable mass of broken *Oculina*, etc. The largest pair of these appendages is situated just above and behind the orbits. The next largest pair is on the nape, just anterior to the branchial aperture. Pairs of filaments are situated irregularly along the dorsal and ventral surfaces. On the segments of the trunk rings are peculiar radiating striae; and a raised boss marks the centre of each segment. On the tail rings the bosses are very conspicuous and the ornamental striae less so.

HIPPOCAMPIDAE.

Hippocampus sp. Sea Horse.

One exceedingly small specimen taken in the tow-net off Flatts Inlet one night during July. I have been unable to determine the species. Sea-horses are well known to the natives, and are said to be common at certains seasons.

ATHERINIDAE.

Menidia notata (MITCHILL).

Distribution. — Coast of United States southward to the Carolinas.

D. 6 + 9; A. 1, 23.

There is one specimen of this species in the collection of the M. C. Z. (No. 18,246); so far as I can ascertain no other specimen has ever been taken.

M. menidia (LINNÉ). Blue Fry.

Distribution. — Atlantic coast of United States, the Carolinas southward.

D. 4 + 9; A. 1 + 22.

This species was exceedingly common in Flatts Inlet. Thousands were seined daily by the natives for bait.

MUGILIDAE.

Mugil brasiliensis AGASSIZ. Mullet.

M. liza Cuv. & Val. Goode, '76ᵃ, p. 63.

Distribution. — West Indies; Atlantic coast of South America.

D. 5 + 8; A. 3 + 8.

Specimens were frequently taken from the seine in Flatts Inlet; the species is generally common.

M. curema CUV. & VAL.

Distribution. — Both coasts of the Americas.

D. 5 + 5; A. 3 + 9.

I obtained a large number of specimens of this species in March and April, 1903, at Hungry Bay. During the summer, however, only one specimen was taken; this was from *Sargassum* floating off Ireland Island. The species has not been taken before at Bermuda.

SPHYRAENIDAE.

Sphyraena sphyraena (LINNÉ.)

S. spet (Haüy) Goode, '76ᵃ, p. 61.
Jordan & Evermann, '96–00, vol. 1 (1896), p. 826.

Distribution. — Southern coast of Europe to Bermuda.

D. 6 + 9; A. 1 + 9.

This European species is not uncommon about Bermuda. I have a single specimen about 10 inches long taken in the seine near Gibbet Island and another, considerably smaller, taken by the members of the Biological Station during the summer of 1904.

HOLOCENTRIDAE.

Holocentrus ascensionis (Osbeck). Squirrel.

Holocentrum sogo Bloch. Goode, '76^{a}, p. 49.

Distribution. — Florida and Cuba to St. Helena.

D. 11 + 15 ; A. 6 + 10.

This species is very common in sheltered nooks about the rocky shores and reefs. It is nocturnal and great numbers were sometimes taken in a few hours at night in the fish pots.

H. puncticulatus, sp. nov.

(Plate 2.)

D. 11 + 13 ; A. 4 + 8 ; ll. 45; ltr. 3 + 8.

Near *H. siccifer* Cope, but differing in the number of rays in the anal fin, in the shape of the dorsal fins, and in color.

Head with spines 2⅓, depth 2¾. Spinous dorsal rather long and elevated anteriorly ; soft dorsal not as high as spinous portion. Second anal spine and first anal soft ray about the same length and almost reaching the base of the caudal. There is one strong spine on the preopercular bone and one on the opercular. The posterior and ventral edges of both these bones are strongly serrate. The interorbital keels are rather weak, and each divides posteriorly into nine, spreading out in a fan-like manner.

The color in life is bright rosy red with nine lateral series of very fine black and dark brown dots; growing fainter and fewer ventrally. A large black spot appears on the membrane of the first three dorsal spines, and also on the spines themselves. The rest of the fins are rosy white, except for a few extremely faint dusky patches on the posterior part of the first dorsal.

This species is represented by the single type specimen (M. C. Z. No. 29,054), Flatts Inlet, Bermuda Is. Taken in a fish trap in about 10 ft. of water. The species is rather common, and other specimens were seen.

MULLIDAE.

Upeneus maculatus (Bloch). Goat fish.

Hypeneus maculatus (Bloch) Cuv. Goode, '76^{a}, p. 49.

Distribution. — West Indian region.

D. 8 + 8 ; A. 2 + 6.

Probably common in rather deep water outside the reef. One specimen was taken in a fish pot off Hungry Bay by a fisherman, who said that the species was not uncommon, and another from the stomach of a large grouper (*Epinephelus striatus*).

CARANGIDAE.

Decapterus punctatus (Agassiz). Robin.

Goode, '76, p. 46.

Distribution. — Mass. to Brazil.

D. 3 + 30 (31); D. 3 + 25. Sc. 40 about.

I have four specimens, two taken by Dr. A. S. Bickmore (M. C. Z. No. 17,054), and two taken in Harrington Sound in July, 1903. This species is common at times, but it is at other times quite impossible to find a single specimen. They take bait best at night in moderately deep water.

Seriola zonata (Mitchill). Crevalle.

Goode, '76^a, p. 75.

Distribution. — Massachusetts to the Carolinas.

D. 8 + 38; A. 3 + 21.

One specimen taken on the Challenger Banks. I saw quite a number of these brought in by the Hamilton fishermen. They were usually taken far off shore.

Trachurops crumenophthalmus (Bloch). Goggle-eye.

Goode, '76^a p. 47.

Distribution. — Coast of Atlantic Ocean (except Europe). Pacific off Central America and Mexico.

D. 8 + 26; A. 3 + 22. Sc. 36.

One specimen about two inches long was taken from *Sargassum* off the Challenger Banks and turned over to me by Professor Mark. The species was very rare at Bermuda all summer. A slightly smaller specimen was taken during July, 1904.

Caranx ruber (Bloch).

Distribution. — West Indies.

D. 8 + 27; A. 2 + 23. Sc. 30.

One specimen taken in the tide rush at mouth of Harrington Sound on hook baited with *Stolephorus*. A second specimen (M. C. Z. 17,360) was taken at Bermuda in 1864 by Capt. Hamilton. This specimen has 31 scutes on the caudal pedicel.

C. hippos (Linné).

Distribution. — Tropical seas.

D. 8 + 21; A. 2 + 17. Sc. 30.

One specimen taken on hook and line in Flatts Inlet in about four feet of water and two specimens from Hamilton (M. C. Z. No. 28,989) are the only representatives of this widely distributed species which I have had an opportunity to examine from Bermuda.

C. crysos (MITCHILL). Jack.

Goode, 76^a, p. 75.
Paratractus pisquetus (C. & V.) Gill. Goode, 76^a, p. 47.

Distribution. — Massachusetts to Brazil.

D. 8 + 25 ; A. 2 + 21. Sc. 45.

I have examined four specimens of this species from Bermuda; three were taken in the summer of 1903 at Flatts Inlet, the other at Hamilton about 1870 (M. C. Z. No. 17338). A number of these fishes were almost always to be found lying in wait for fry carried out of Harrington Sound by the tide. They took bait voraciously and afforded considerable sport for their size. We took none over 9 inches in length. The name Jack is applied to several species.

NOMEIDAE.

Nomeus gronovii (GMELIN).

Jordan & Evermann, '96–00, vol. 1 (1896), p. 949.

Distribution. — Tropical Atlantic.

D. 11 + 26 ; A. 3 + 26.

This species appears to be rather common in Castle Harbor, where the only specimens seen were taken. They usually swim about among the tentacles of the Portuguese-man-o-war, but the only specimen I caught was swimming lazily along near the surface of the water; there were, however, plenty of *Physaliae* near by.

CORYPHAENIDAE.

Coryphaena equisetis (LINNÉ). Dolphin.

Distribution. — Open Atlantic, most common in the tropics.

D. 52 ; A. 25.

A single specimen taken off Bermuda during the summer of 1904. It was said to be very common at all times at some distance off shore.

CHEILODIPTERIDAE.

Apogon binotata (POEY).

Distribution. — Florida, West Indies, and Brazil.

D. 7 + 8; A. 2 + 8.

A single specimen of this species was taken in Castle Harbor, it appears to be rare. Several natives to whom I showed the specimen declared that they had never seen it before. I compared it with Poey's type from Cuba (M. C. Z. No. 8,750) and could find no difference between them.

A. maculata (POEY).

Distribution. — Cuba.

D. 4 + 10; A. 2 + 7; ll. 27, ltr. 2 + 10.

I have five specimens of this handsome species. Three of these were taken in Flatts Inlet; I took one in July, 1903, and Mr. Nichols two in August. The remaining two came from some floating *Sargassum*; one on the Challenger Banks, the other near the main island; both specimens are very small. I was told that the species became very common in Flatts Inlet about the latter half of August.

SERRANIDAE.

Bodianus fulvus (Linné). Nigger fish.

Jordan & Evermann, '96–00, vol. 1 (1896), p. 1144.

Distribution.—West Indies.

This species appears to be very generally distributed over the reefs, and moderately common everywhere.

Epinephelus striatus (Bloch). Grouper, Hamlet.

Goode, '76ª, p. 57.

Distribution. — West Indies to Brazil.

D. 9 + 17; A. 3 + 8.

The most important food fish taken near Bermuda. My specimens are small ones taken in fish pots near Flatts Inlet. It attains a weight of 40 pounds.

E. maculosus (Cuv. & Val.). Hind.

Jordan & Evermann, '96–00, vol. 1 (1896), p. 1158.
E. gutattus (Gmelin) Goode. Goode, '76ª p. 58.

Distribution. — The West Indies generally.

D. 9 + 16; A. 3 + 8.

This species was very common everywhere about the reefs. We took specimens by the hook up to 15 or 16 inches in length near North Rock, where they were especially common. Their power of changing color is highly developed; for they change from almost uniform ruddy to flaming red spotted regularly with deep brown or black.

E. morio (Cuv. & Val.). Red Hamlet.

Distribution. — Southern Atlantic coast of North America southward to Brazil.

D. 9 + 16; A. 3 + 9.

This species was generally taken with *E. striatus*, but was far more rare than that species. It is said to be growing more common year by year.

Mycteroperca venenosa apua (Bloch). Rock-fish.

Trisotropis undulosus (Cuv.) Gill. Goode, '76ª, p. 55.

Distribution. — West Indies, Florida Keys to Brazil.

Grows to a great size and is one of the most important of the common food fishes.

Hypoplectrus puella Cuv. & Val. Mutton Hamlet.

Goode, '76ª, p. 60.

Distribution. — West Indies.

D. 10 + 14; A. 3 + 7.

Not uncommon about rocky shores with very steep banks; but locally distributed. Six specimens were taken in fish pots in Harrington Sound near the bridge and off the dock of the Hotel Frascati.

Paranthias furcifer (Cuv. & Val.). Barber.

Distribution. — Both coasts of Tropical America.

D. 9 + 18; A. 3 + 9.

This species has not been previously recorded from Bermuda. Mr. J. T. Nichols took three specimens, each about 1 foot long, off the south shore near Hungry Bay with hook and line. Two were also among the collection made in July, 1904. The color of all was a dull uniform rose pink.

LUTIANIDAE.

Neomaenis griseus (Linné). Gray snapper.

Lutjanus caxis (Schn.) Poey. Goode, '76ª, p. 54.

Distribution. — West Indies, South Atlantic coast of United States to Brazil.

D. 10 + 14; A. 3 + 8; ll. 51; ltr. 7 + 13.

One of the most common Bermudian fishes; large schools could be seen swimming about in Harrington Sound or Flatts Inlet at any time. About 50 of them spent most of their time under our boat at her moorings, never seemed to be more than a few yards from this location. They are shy and extremely difficult to take. The specimens before me are from Harrington Sound. They appear less shy in Hamilton Harbor, where many are taken on hooks and in fish pots for bait.

N. apodus (Walbaum). Schoolmaster.

Distribution.—West Indies; Florida to Brazil.

D. 10 + 14; A. 3 + 8.

Several specimens taken from both Hungry Bay and Harrington Sound. The young were common in many small coves along this shore, and large specimens are often taken about the outer reefs.

N. vivanus (Cuv. & Val.). Silk snapper.

Distribution. — West Indies.

D. 10 + 14; A. 3 + 8.

A very common species in the deeper water about the outer reefs and in the middle of Harrington Sound. I have several specimens taken with a fish pot in the steamboat channel about opposite Bailey's Bay. This species takes bait well, especially at night, and affords fair sport.

N. hastingsi BEAN. Spot snapper.

Bean, '98, p. 45.

Distribution. — The Bermudas.

D. 10 + 14; A. 3 + 8.

One specimen of this species was turned over to me by Prof. E. L. Mark; it was taken on the Challenger Banks. Dr. Bean states that this is the "silk snapper" of the native fishermen; but so far as I could ascertain from numerous inquiries, that name is only used for *N. vivanus* (C. & V.).

Ocyurus chrysurus (BLOCH). Yellow tail.

Goode, '76ª, p. 55.

Distribution. — West Indies to Brazil.

D. 10 + 13; A. 3 + 9; ll. 66; ltr. 7 + 16.

This species was very common in Harrington Sound, where large numbers were sometimes taken using "scuttle" (*Octopus rugosus*) for bait. My specimens are from fish pots in Flatts Inlet and Harrington Sound. The species attains a weight of 5 lbs.

HAEMULIDAE.

Haemulon macrostomum GÜNTHER. Sow grunt.

Distribution.—West Indies generally.

D. 12 + 16; S. 3 + 8.

This species was frequently brought into Hamilton by the fishermen, who took it in rather deep water near the outer reefs, usually in company with *Haemulon album.*

H. carbonarium POEY. Bull grunt.

Jordan & Evermann, '96-00, vol. 2 (1898), p. 1300.

Distribution. — West Indies.

D. 12 + 16; A. 3 + 8.

This fish was not at all uncommon off the South shore; it was rarely taken anywhere else. We have several specimens from about one mile south of the mouth of Hungry Bay.

H. sciurus (SHAW). Striped grunt.

Distribution. — West Indies generally.

This fish was taken occasionally in fish pots off the South shore and in Hamilton Harbor. It did not appear to be nearly as common as *H. flavolineatum.* There are two specimens (M. C. Z. No. 10,555) which were taken in 1862 by Dr. Bickmore.

H. flavolineatum (Desmarest). Yellow grunt.

Jordan & Evermann, '96–00, vol. 2 (1898), p. 1306.

Distribution. — West Indies.

This species is very common everywhere about Bermuda. There are thirty-four specimens in the Museum which were taken by Dr. A. S. Bickmore in September, 1862 (M. C. Z. Nos. 10,526, 10,541). It does not usually grow to a size suitable for food. A large number were taken during August, 1903, in Harrington Sound.

Orthopristis chrysopterus (Linné). Sailor's choice.

Distribution. — Atlantic and Gulf coasts of the United States.

D. 13 + 16; A. 3 + 12.

This species was quite common in Hamilton Harbor, though I never saw a single example elsewhere in the Bermudas.

Bathystoma striatum (Linné).

Jordan & Evermann, '96–00, vol. 2 (1898), p. 1310.

Distribution. — Bermudas to South America.

D. 13 + 13; A. + 37.

Common, particularly in Flatts Inlet, where it may be taken any day usually associated with very large numbers of *B. rimator.* There are twenty specimens (M. C. Z. No. 10,602) which were taken by Dr. Bickmore in 1862.

B. rimator (Jordan & Swain). White grunt.

Distribution. — East coast of United States and West Indies.

D. 13 + 15; A. 3 + 8.

An excessively common species in Flatts Inlet, less so elsewhere. I have specimens taken in a fish trap in Harrington Sound and Flatts Inlet; any number could have been collected.

SPARIDAE.

Calamus calamus (Cuv. & Val.). Porgy.

C. megacephalus (Swainson) Poey. Goode, '76^{a}, p. 51.
C. orbitarius Poey. Goode, 76^{a}, p. 51.

Distribution. — West Indies and Florida.

D. 12 + 12; A. 3 + 10.

The fishermen recognize two "Porgies": the "Goat head," and the "Sheep head." I think, however, that both species are referable to *C. calamus*, for they did not seem to be very certain as to just what constituted a "Goat head" or "Sheep head" porgy.

Diplodus sargus (Linné). Bream.

Jordan & Evermann, '96–00, vol. 2 (1898), 1363.
Sargus variegatus (Lacépède), Goode. Goode, '76^a, p. 52.

Distribution. — Coast of Southern Europe, westward to Bermuda.

D. 12 + 13 (14); A. 3 + 13 (14).

One of the commonest shoal water species. It was strangely confused with *Kyphosus sectatrix* by Goode.

GERRIDAE.

Eucinostomus gula (Cuv. & Val.). Shad.

Goode, '76^a, p. 39.

Distribution. — New York (rarely) to Brazil.

D. 9 + 10; A. 3 + 8.

Common, generally associated in small schools with the young of *Neomaenis griseus* and *Mugil brasiliensis.*

KYPHOSIDAE.

Kyphosus sectatrix (Linné). Chub.

Pimelepterus boscii (Lacépède). Goode, '76 , p. 52.

Distribution. — Pelagic in North Atlantic; West Indies.

D. 11 + 12; A. 3 + 11.

This species may be called an irregular, though usually very common, visitor at Bermuda.

POMACENTRIDAE.

Abudefduf saxatilis (Linné). Cow pilot. Sergeant major.

Glyphidodon saxatilis (Linné) Cuvier. Goode, '76^a, p. 38.

Distribution. — Both coasts of Tropical America.

D. 8 + 13; A. 2 + 12; ll. 28; ltr. 11 + 5.

I have about twenty specimens of this species varying in length from a half inch to four inches, the latter being a large one for the shores of Bermuda. I saw a very large specimen in a rock pool at North Rock. Native fishermen state that the species attains a weight of one and one half pounds in the deep water off the Rock. It is very common everywhere.

Furcaria cyanea Poey.

Distribution. — Cuba.

D. 12 + 12; S. 2 + 12.

A single specimen from Bermuda taken in 1864 by Captain Hamilton (M. C. Z. No. 14,801). I can find no other record for the occurrence of this species except off Cuba.

Microspathodon chrysurus (Cuv. & Val.).

Distribution. — West Indies.

Two very small specimens from *Sargassum* off Ireland Island. The species does not appear in previous lists, so far as I am aware.

Eupomacentrus leucostictus (Müller & Troschel). Cock-eye pilot.

Distribution. — West Indies; Florida.

D. 12 + 15; A. 2 + 13.

Although with considerable hesitation, I refer to this species a number of Pomacentroids which were taken in various localities, about the Islands. The genus is in a very confused condition, and I have no desire to describe these specimens as new until a more extensive examination of existing material can be made.

E. fuscus (Cuv. & Val.). Brown cock-eye pilot.

Verrill, :01, p. 56.

Distribution. — Florida to Brazil; West Indies.

Specimens which may be this species are very common in many localities especially at the head of Hungry Bay, both among the loose rocks of the Spit and among the roots of the mangroves.

LABRIDAE.

Lachnolaimus maximus (Walbaum). Hog fish.

Jordan & Evermann, '96-00, vol. 2 (1898), p. 1579.
L. falatus (L.). Goode, '76ª, p. 36.

Distribution. — West Indies.

D. 14 + 11; A. 3 + 10.

An important and common food fish, growing to the size of about twenty pounds.

Iridio radiatus (Linné). Lady fish. Blue fish.

Jordan & Evermann, '96-00, vol. 2 (1898), p. 1590.
Choerojulis radiatus (L.) Goode. Goode, '76ª, p. 35.

Distribution. — West Indies; Florida to Brazil; St. Paul's rocks.

Not uncommon a short distance off the South shore.

I. cyanocephalus (Bloch). Blue head.

Distribution. — West Indies to Brazil.

Rather rare; the few which we have were taken on the reef off the south shore. This is the most northerly record for the species.

I. garnoti (Cuv. & Val.).

Distribution. — West Indies.

One small specimen obtained in Castle Harbor. The species has not been recorded from Bermuda before.

I. bivittatus (Bloch). Slippery Dick.

Platyglossus bivittatus Bloch. Goode, '76ª, p. 75. Garman, :00, p. 510.

Distribution. — West Indies; Carolinas to Brazil.

D. 9 + 11; A. 3 + 12.

Very common everywhere.

Chlorichthys nitidissimus (Goode). Slippery Dick.

Jordan & Evermann, '96–00, vol. 2 (1898), p. 1608.

Distribution. — The Bermudas.

Rather common about the outer reefs.

SCARIDAE.

Sparisoma abildgaardi (Bloch).

Distribution. — West Indies to Brazil.

D. 9 + 10; A. 2 + 9.

This and the three following species are all called Parrot fishes. I have a single specimen of this species taken in a fish pot off the south shore. It does not appear to have been recorded from so far north before.

S. viride (Bonnaterre).

Distribution. — West Indies.

D. 9 + 10; A. 2 + 9.

A single specimen, which was taken with the preceding species, is the only one we obtained. The natives consider it very rare.

Scarus croicensis (Bloch).

Pseudoscarus sanctae-crucis Günther. Goode, '76ª, p. 75.

Distribution. — West Indies generally.

D. 9 + 10; A. 2 + 9.

Not uncommon in Castle Harbor and occasional in Flatts Inlet. There are several specimens taken from both localities in the collection made in the summer of 1903.

S. caeruleus (Bloch).

Pseudoscarus caeruleus (Bloch) Günther. Goode, '76ª, p. 33.
P. psittacus Goode, '76, p. 75.

Distribution. — West Indies, on our coast, rare.

D. 9 + 10; A. 2 + 9.

Not uncommon.

CHAETODONTIDAE.

Chaetodon ocellatus (Bloch). Butterfly fish.

Distribution. — Cuba; Gulf Stream northward.

Rather rare about the outer reefs; but said by the fishermen to be increasing rapidly in numbers.

C. capistratus (Linné). Four eyes.

Goode, '76^a, p. 75.

Sarothrodus bimaculatus (Bloch) Poey. Goode, '76^a, p. 43.

Distribution. — West Indies.

D. 12 + 19; A. 3 + 17.

Common in many localities about Hamilton Harbor, Harrington Sound, and Castle Harbor.

Angelichthys ciliaris (Linné). Angel fish.

Holacanthus ciliaris (Linné) Lacépède. Goode, '76^a, p. 43.

Distribution. — West Indies and Florida.

D. 14 + 21; A. 3 + 21.

An important food fish, very common about the reefs and steep shores. For some reason the specimens taken off the north shore are considered much more palatable than those taken off the south shore.

TEUTHIDIDAE.

Teuthis hepatus (Linné). Blue tang.

Acanthurus chirurgus (Bloch.) Schn. Goode, '76^a, p. 42.

Distribution. — The West Indian region.

D. 9 + 24; A. 3 + 22.

A few specimens were obtained, but the species did not appear to be as common as the following, with which it was almost always associated.

T. bahianus (Castelnau). Doctor fish.

Distribution. — West Indies; both coasts of Tropical America.

D. 9 + 25; A. 3 + 23.

Decidedly abundant about the reefs and steep shores. Though the adults did not run up into Flatts Inlet, the young were frequently seen there.

T. helioides, sp. nov. Yellow doctor.

(Plate 3.)

D. 9 + 26; A. 3 + 26.

Most nearly related to *T. chrysosoma* (Bleeker) from the Sea of Kajeli. Form ovate; height of body rather more than one half of total length (caudal fin included). The profile of the snout is slightly concave. There are five incisors on each side of the upper jaw. The upper lobe of the caudal fin is slightly longer than the lower. The scales of the body are very minute. In life the color was brillant yellow, which has changed in spirits to a dull lustreless yellow. The dorsal, anal, and ventral fins are edged with dusky brown, almost black in some places. There is a diffuse patch of light brown on the operculum.

Type (M. C. Z. No. 29,053) a single specimen five inches long taken near Cooper's Island, in Castle Sound, Bermudas, by Messrs. O. Bryant and J. T. Nichols.

BALISTIDAE.

Balistes carolinensis GMELIN. Turbot.

B. capriscus GMELIN. Goode, '76^a, p. 25.

Distribution. — Tropical Atlantic, Mediterranean Sea.

D. 3 + 27 ; A. 25.

We took several specimens in fish pots in about five fathoms off Flatts Inlet, and I have also one very small one from *Sargassum* of the Challenger Banks given me by Mr. J. T. Nichols. The species grows to considerable size and is frequently eaten, although the flesh is dry and tasteless.

B. vetula LINNÉ. Queen turbot.

Goode, '76^a, p. 26.

Distribution. — West Indian region generally.

D. 3 + 29 ; A. 27.

Not taken by Goode, but nevertheless rather common. A regular visitant at Bermuda, as several are taken every year. The specimen before me was brought into the Biological Station during the summer of 1904.

MONACANTHIDAE.

Alutera scripta (OSBECK).

Goode, '76^a, p. 28.

Distribution. — Tropical seas of both hemispheres.

D. 1 + 47; A. 51.

A single specimen of this species was speared at Bermuda during the summer of 1904 and obtained by Professor Mark.

TETRAODONTIDAE.

Spheroides spengleri (BLOCH). Puffer.

Chilichthys spengleri (Bloch).
Goode, '76^a, p. 22.

Distribution. — Eastern Atlantic.

D. 7; A. 6.

One specimen from Hungry Bay, two inches long, taken by Mr. Nichols and one specimen from the dredge, one inch long, among the reefs off Ireland Island in 8–10 fms. This species did not appear to be at all common and no adults were seen. While collecting invertebrates Mr. Bigelow and I both saw several large "puffers" which appeared to be *S. testudineus*, and I have no doubt that this species will occur in future collections.

SCORPAENIDAE.

Scorpaena agassizii Goode & Bean.

Goode & Bean, '96, p. 247.

Distribution. — West Indian region.

One specimen dredged on the Challenger Bank, by the members of the Biological Station, in forty fathoms.

CEPHALACANTHIDAE.

Cephalacanthus volitans (Linné).

Distribution.—Tropical Atlantic, widely distributed.

D. 2 + 4 + 8; A. 6.

One specimen was taken on the beach at Gibbet Island on June 19, 1903. The species is very rare at Bermuda, and was not known to any of the fishermen that saw the specimen. I learned, however, from Mr. F. Goodwin Gosling, Secy. of the Bermuda Natural History Society, that one specimen had been taken during the spring in Hamilton Harbor.

CALLIONYMIDAE.

Callionymus bermudarum, sp. nov.

D. 3 + 7 ; A. 4.

Most nearly related to *C. pauciradiatus* Gill; but differing in the number of rays in the second dorsal and in the preopercular spine. Besides giving the radial formula for his specimen (D. 3, 6; A. 3), Gill ('65, p. 144) says : —

"The preopercular spine is armed with three teeth above and terminates behind in an acute point."

A description of the three specimens from Bermuda follows : —

Head (to tip of opercular spine) 3½ times in total length ; depth 8 times. Ventral surface of body flat ; without a bordering fold of skin ; a single lateral line ; diameter of eye a little less than length of snout. The maxillary reaches about ½ the distance to the eye. The preopercular spine is armed with two barbs directed forward and situated dorsally ; there is also a sharp termination to the spine itself, which is directed straight backward. The gill opening is a very minute slit, also directed backward. In one specimen the first dorsal ray reaches the base of the caudal ; each of the other two being successively a little shorter. In the other two specimens the length of the dorsal is about equal to the distance from the posterior border of the eye to the tip of the snout. The pectoral fins are about as long as the head; the ventrals slightly shorter. The color of these specimens is a milky white, irregularly banded and blotched with light brown. In the largest one (with the filamentous dorsal) the anal fin is rather dark brown and there is a dark spot on the ventral fin and on the middle of the throat, nearly covering it.

Type series, three specimens (M. C. Z. No. 29,055) 1¼″, 1″, ¾″, lg. from Bermuda. Taken by the dredge in from 6–8 fms.; Aug. 1903, the largest off Castle Island, the others off Ireland Island.

GOBIIDAE.

Gobius stigmaturus Goode & Bean.

Garman, :00, p. 510.

Distribution. — Bermuda.

D. 4 + 12 ; A. 12.

One specimen from Hungry Bay was taken from under a stone at low tide in about four inches of water by my brother, Mr. W. W. Barbour, April, 1903; a diligent search in the same and similar localities failed to yield a second specimen.

G. soporator Cuv. & Val. Molly miller.

Goode, ’76^{a}, p. 75.

Distribution. — The West Indian region and Northern South America.

D. 6 + 10; A. 1 + 7.

The forty-eight specimens before me show a decided differentiation into two distinct color phases. One lot, consisting of twenty-six specimens, was taken by me, with the aid of Messrs. Bigelow and Cole, in the rock pools of the south shore near Hungry Bay. All these specimens, except two, which are quite black, are very dark brown. The rest, some twenty or more, were taken by dredging in Castle Harbor and Mangrove Bay, in localities where the bottom was white sand composed of coral, shell, and Foraminifera. All these specimens are light gray, almost white, with a row of dark lateral puncticulations, just visible.

This species is very active and jumps about on the bare rocks washed by the waves and even moves from one tide pool to another over dry land.

BLENNIIDAE.

Labrisomus nuchipinnis (Quoy & Gaim.). Molly miller.

Labrosomus nuchipinnis (Quoy & Gaim.) Poey. Goode, ’76^{a}, p. 28.

Distribution. — West Indies and coast of Southern States.

D. 18 + 12; A. 2 + 17.

I collected four specimens of this species in March, 1903, all of a characteristic mottled brown color. In July, 1903, I took eight more, four of which showed the same color as those taken in the early spring. The others were gorgeously bright with yellow, red, and orange about the foreparts of their bodies. These were all males, the darker ones being females with eggs almost ready to hatch.

I had an opportunity to watch a pair of these fishes getting ready to lay. The female would move swiftly about in the sand under a protecting rock, thus scooping out a hollow place in which she probably deposited her eggs. In a few days the female, looking thinner, lay quite still near the hollow in the sand, where I presume the eggs had been laid; the male was swimming nervously about as if to drive away intruders. Up to the time I left, more than a month after the probable laying of the eggs, the male, with the same gaudy color, was still swimming about; the female was gone, and I presume the young had been hatched and had long since departed.

Salariichthys textilis (Quoy & Gaim.). Molly miller.

Salarias textilis, Quoy & Gaim. Goode, '76ᵃ, p. 29.

Distribution. — Bermudas to Northern South America.

Very common in tide pools about the shores and at North Rock.

BROTULIDAE.

Brosmophysis verrillii Garman.

Garman, :00, p. 511.

Distribution. — Bermuda.

D. 71; A. 52; ll. 98; ltr. 25.

Several specimens of this little known Brotuloid were taken by Mr. H. B. Bigelow and myself from the rock pools near Flatts Inlet and Gibbet Island. A diligent search at Bailey's Bay, the type locality, and in many other likely places failed to reveal a single specimen.

PLEURONECTIDAE.

Platophrys lunatus (Linné). Plate fish.

Distribution. — West Indies generally.

Apparently the only flat fish which is common about Bermuda. Several were taken during my stay in the summer. The only specimen which I had an opportunity to observe carefully was one loaned to Professor Mark by Mr. L. Mowbray of St. George's.

ANTENNARIIDAE.

Pterophryne gibba (Mitchill). Mouse fish.

Distribution. — West Indies generally.

D. 3 + 12; A. 7.

Very common in the *Sargassum*. I have about sixty specimens, a few of which were taken from the dredge off Ireland Island.

P. ranina Tiles.

Distribution. — Fields of sea weed in the Tropical Atlantic, Richardson.

A single large pediculate was obtained from a colored fisherman and handed to me by Professor Mark. It is evidently Cuvier's *Chironectis laevigatus* and also agrees remarkably well with Richardson's (**'44–48**, p. 15, pl. 9, Fig. 354), *Chironectis pictus* var. *vittatus.*

Antennarius stellifer, sp. nov.

(Plate 4.)

D. 3 + 12; A. 7; V. 5; P. 10; C. 9.

Closely related to *A. nuttingii* Garman; but differing conspicuously in coloration, size, and form of bait.

In form this species is short and extremely bulky anteriorly. The caudal peduncle is short and compressed. The head is as wide as high; with a rather deep, scaleless concavity behind the second dorsal ray. The mouth is very wide, almost vertical, and the eye is small. The first dorsal ray is extremely long and slender, a little more than 2½ times the length of the second dorsal ray. On the posterior surface of the second dorsal ray there is a peculiar fringe of elongate scales, a tuft of similar scales being situated on each side of the naked occipital depression. The base of the first dorsal ray is a prominent movable pedicel. The second dorsal ray is quite free, while the third is connected with the dorsum by the skin. The soft dorsal is composed of two regions; the anterior five rays are of equal size and their tips do not extend beyond the connecting membrane. The condition in the posterior part of the fin is very different; the rays do project beyond the membrane, and from the sixth to eighth ray the height of the fin increases regularly, while from the ninth to twelfth the decrease is as regular, so that the posterior portion is more or less fan-shaped. The bait on the tip of the first dorsal ray is a tiny sphere, from which spring numerous delicate filaments.

The color of this species, described from the alcoholic specimen, is as follows: — The entire body is very dark brown, almost black with areas of deep velvety black, which are sometimes surrounded in a zone of lighter brown. The bait, posterior surface of second dorsal ray and under surface of the pectoral and ventral fins is dirty white. There is on each side of the body an irregularly stellate figure of white composed of a central patch and radiating spots. A white saddle is situated on the caudal peduncle.

Only one specimen known, the type (M. C. Z., No. 29,056), obtained in Castle Harbor by Mr. L. Mowbray of St. George's, and procured from him by Professor Mark.

A. scaber (Cuv.)

Distribution. — West Indian waters.

A single specimen from Bermuda was obtained in exchange from the Boston Society of Natural History. It had been in the collection for some time.

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EXPLANATION OF PLATES.

PLATE 1.

Siphostoma dendriticum, sp. nov. (p. 115).
Four (4) times natural size

PLATE 2.

Holocentrus puncticulatus, sp. nov. (p. 117),
Twice natural size.

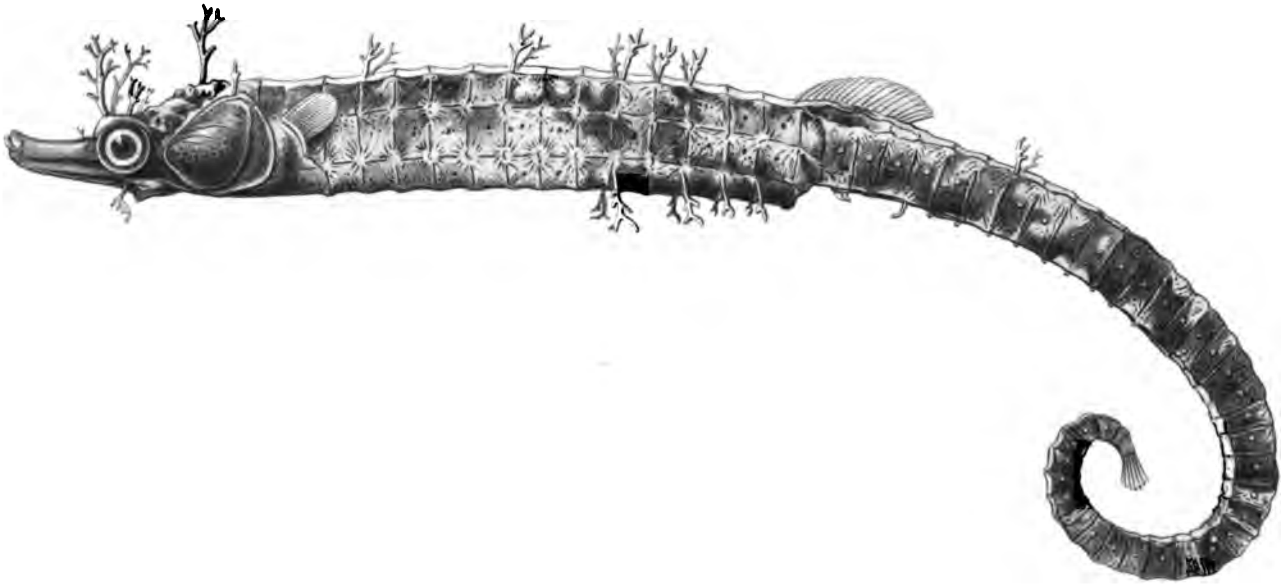
PLATE 3.

Teuthis helioides, sp. nov. (p. 127).
Natural size.

PLATE 4.

Antennarius stellifer, sp. nov. (p. 132).
Very slightly enlarged.

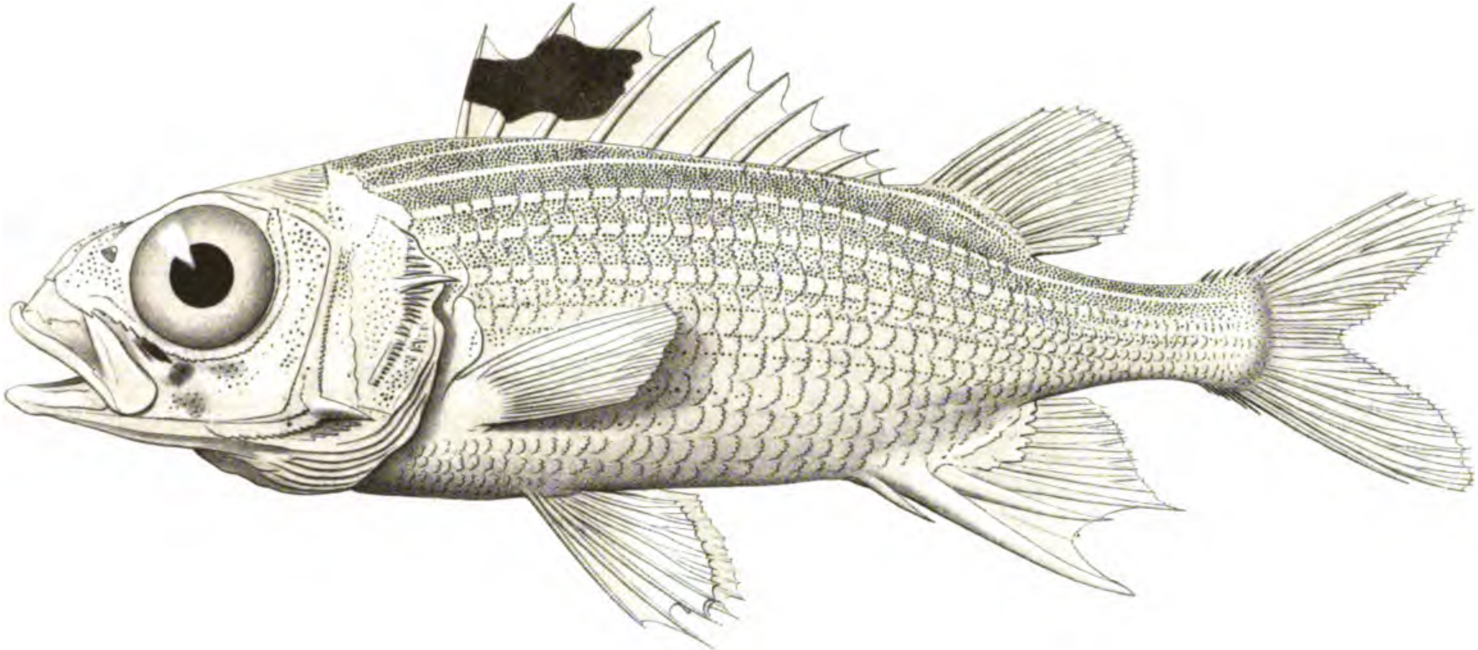
PLATE 1.



F. N. Fischer del

B. Meisel lith.

PLATE 2.



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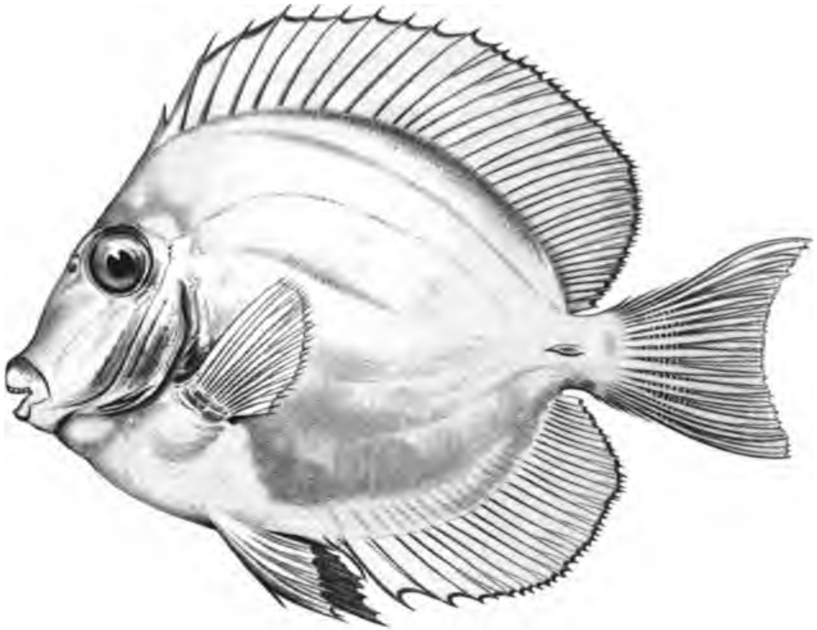

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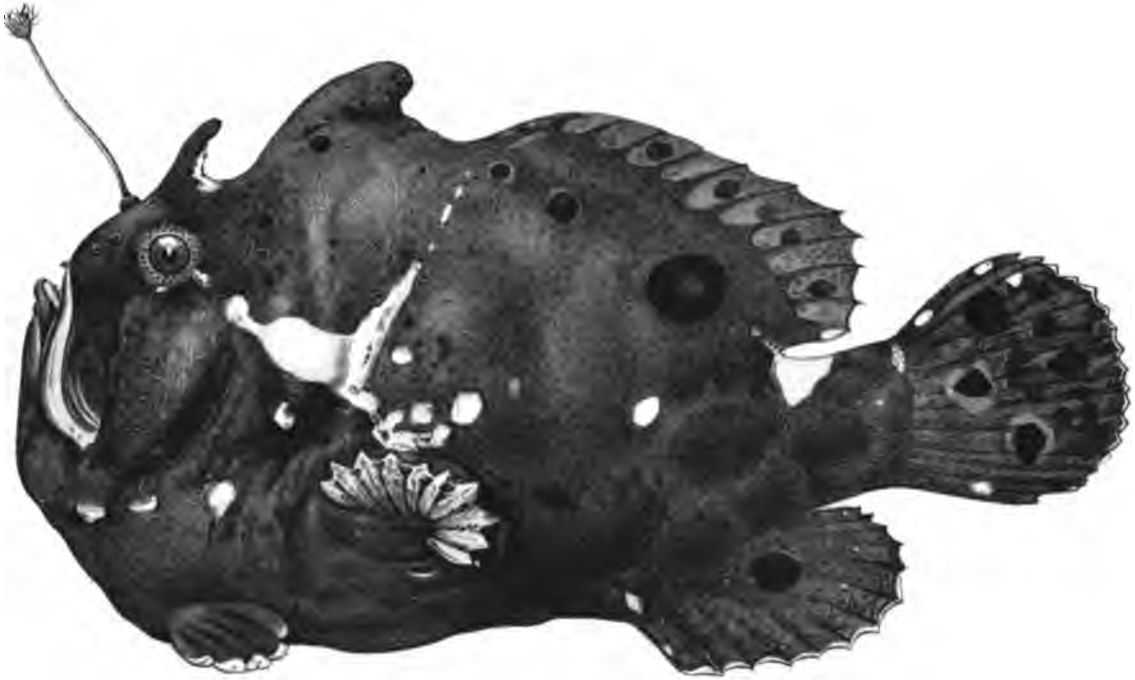
BARBOUR - BERMUDIAN FISHES

PLATE 4



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FOR RESEARCH.

No. 8.

THE SPERMATOGENESIS OF THE MYRIAPODS. IV. ON THE KARYOSPHERE AND NUCLEOLUS IN THE SPERMATOCYTES OF SCOLOPENDRA SUBSPINIPES.

By Maulsby W. Blackman

With a Plate.

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THE SPERMATOGENESIS OF THE MYRIAPODS.

IV.—ON THE KARYOSPHERE AND NUCLEOLUS IN THE SPERMATOCYTES OF SCOLOPENDRA SUBSPINIPES.*

By Maulsby W. Blackman.

Presented by E. L. Mark. Received June 14, 1905.

In making a comparative study of the spermatogenesis of different species of chilopods the phenomena observed in Scolopendra subspinipes are in some respects so markedly different from those already reported as characteristic of S. heros (Blackman, :02 and :05) as to warrant their treatment in a separate paper. The most striking differences are dependent upon the fact that a large plasmosome, or true nucleolus, is present within the nucleus of the spermatocytes of S. subspinipes during stages of mitotic inactivity, while in the cells of S. heros no such structure is to be found. The presence of this body in S. subspinipes seems to necessitate a corresponding variation in the behavior of the chromatin. Although these differences are often quite marked, the process is essentially similar in the two species.

The material upon which this paper is based was collected by the author near Flatts, Bermuda, during July, 1903. I am glad of this opportunity of thanking Dr. E. L. Mark, director of the Bermuda Biological Station, for numerous courtesies extended to me while working in the laboratory.

The testes obtained from Scolopendra subspinipes are not so far advanced in development as those of S. heros, used in observations recorded in my former papers (Blackman, :03 and :05). Very few spermatozoa, spermatids, and secondary spermatocytes are to be found, nearly the entire bulk of the testis consisting of growing spermatocytes and cells in what I have elsewhere (:05) designated as the vesicle stage. The proportion of cells of the smaller type does not seem to be as great as that found in S. heros (Blackman, :01, :05) or in S. morsitans (P. Bouin, :03). This may be, and probably is, due to the age of the individuals; for I have concluded from a study of the cells of the two types in S. heros that the difference in size is due to differences in nutrition.

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* Contributions from the Bermuda Biological Station for Research, No. 8.

The testes were fixed in Gilson's fluid, embedded in paraffine, and reduced to sections 3 to 5 micra thick. These were stained in Heidenhain's iron-haematoxylin (some were counterstained with Congo red), and studied under a magnification of from 1200 to 1800 diameters.

The spermatogonia of S. subspinipes in the resting stage are similar in all respects to those of S. heros. They are small cells containing an oval nucleus, in which no indication of chromatin can be observed except the large, deeply staining nucleolus-like body, the karyosphere. During the prophase small granular aggregations of chromatin appear (Figure 1), and at the same time the karyosphere becomes so altered as to show conclusively that, as in the sister species, the chromosomes are derived from its substance.

After the formation of the chromosomes from the karyosphere in S. heros nothing of this body remains except the accessory chromosome. In the present species, however, the residue is different. It consists of two parts, a small, deeply staining chromatic body, the accessory chromosome, and a larger, less dense part, the plasmosome (Figure 1). The latter part does not retain the haemotoxylin, but is nearly colorless, or assumes a reddish-brown tint, when the haematoxylin is followed by Congo red. During the later part of the prophase the plasmosome is dissolved, and in the metaphase and later stages of mitosis no indications of such material are to be found (Figure 2).

The phenomena occurring during the later stages of the last spermatogonium seem to be identical in all essential respects to those already described as existing in S. heros. At the end of the anaphase the chromosomes are massed together so closely at opposite poles of the elongated cell as to make their outlines indistinguishable (Figure 2). Later, during the telophase, these chromosomes still aggregated into a dense mass, lengthen out into slender granular segments (Figure 3). A single element, however, the accessory chromosome, does not assume this granular condition, but retains its homogeneous appearance and is on this account very conspicuous (Figure 3).

Upon the reconstruction of the nuclear membrane the segments of chromatin become distributed throughout the nuclear space (Figures 4, 5), causing the cells at this stage to bear a close resemblance to the sperm cells of insects in the spireme condition. Here, however, the chromatin is not a continuous thread, as it is said to be in the cells of many animals, but is in the form of a number of granular segments, one half as numerous as the ordinary chromosomes of the spermatogonia.

These chromosomes are produced by the union in pairs of the chromosomes of the division period. That this is an end to end union is very strongly indicated, although not definitely proved, by the appearance of the chromatin segments at this stage. In Figures 4 and 5 the nuclear vesicle is occupied by a number of slender granular chromatin segments, each of which is bent near its middle, forming a V-shaped figure. At the angle of the V, which doubtless represents the point of union of the two component elements, the chromatin is often interrupted in such a manner that the halves of the segment seem to be connected by only a strand of linin. These conditions in Scolopendra are quite similar to those described by Montgomery (:00) in Peripatus, and later (:01) in Hemiptera, and they lead to the same conclusion as did the more convincing observations made by Sutton (:02) on Brachystola. The latter author has shown conclusively that the synapsis of the chromosomes occurs during the telophase of the last spermatogonium, and that it is brought about by an end to end union of entire spermatogonial chromosomes.

Thus in S. subspinipes the pseudo-reduction of the chromosomes is accomplished in exactly the same manner as in S. heros. Up to this stage (Figure 4) the appearance of the accessory chromosome has been entirely similar to that in S. heros, but from now on the behavior of all of the chromatin is quite noticeably different. This is evidently due to the introduction within the nucleus of a new structural element, — the true nucleolus, or plasmosome.

The first indication of the nucleolus in the spermatocyte is seen at the stage when the nuclear membrane has just been re-formed (Figure 5). At this time a transparent, non-stainable structure appears upon one side of the accessory chromosome. This fundament of the nucleolus at first has very much the appearance of a vacuole occupying one side of the accessory chromosome (Figure 5).

In the telophase of the last spermatogonial division the accessory chromosome, when it first becomes distinguishable from the other chromosomes, is of an oval shape (Figures 3, 4), but after the origin of the plasmosome the compound element thus arising is at first spherical. The chromatin representing the accessory chromosome assumes a crescent shape and nearly surrounds the unstained part — the plamosome. In this manner the accessory chromosome forms one half or more of the outline of the sphere (Figures 5, 8 *b*).

With the reappearance of the nuclear membrane the cell enters upon a period of phenomenal growth and the nucleolus increases in size very rapidly, while the accessory chromosome remains of nearly the same size. Stages in this growth of the nucleolus are shown in Figures 6, 7, and 8, *b*, *c*, *d*, *e*. As the nucleolus grows it also changes in its reaction to stains, and assumes the diffuse brownish tint characteristic of the plamosome when stained with iron-hamotoxylin (Figure 8 *c*). Its shape also is so altered that from now on it is an approximate sphere, upon one side of which lies the deeply stained accessory chomosome. This body, which has again assumed an oval shape, is usually not embedded in the plasmosome, but is closely apposed to one side of it (Figures 8 *f*, 9). Quite often there is a cup-like depression in the plasmosome at the place where the accessory chromosome comes into contact with it (Figure 10).

It is during the period represented by Figures 4 to 19 that the most striking and interesting differences between the germ cells of Scolopendra subspinipes and S. heros occur. These variations, as I have already intimated, primarily concern the arrangement and behavior of the chromatic structures.

The conditions in S. heros are briefly as follows: Upon the reconstruction of the nuclear membrane after the last spermatogonial division, the cells, now containing the number of chromatin segments characteristic of spermatocytes, "enter upon a period remarkable for the extraordinary changes which take place in their structure." Of these changes the most remarkable are the enormous increase in the size of the cells and the peculiar and characteristic arrangement of the chromatin.

Concerning the growth of the cells in S. heros it is sufficient to say that the diameter of the large spermatocytes is about ten times that of the spermatogonia from which they arise. As regards the chromatin structures, I may quote from one of my papers cited (:03): "As the cell continues in its growth the chromatin segements become larger and more diffuse. They no longer retain the stain with the persistency which has characterized them heretofore. Gradually they break down and their substance is accumulated about the accessory chromosome, thus seemingly increasing this element greatly. This process continues until all of the chromatin of the cell is aggregated in one large, intensely staining body situated peripherally in close contact with the nuclear membrane." This body, the karyosphere, is not a homogeneous mass of chromatin, but, "on the contrary, is a rather complex structure, consisting of chromatin, linin, and karyolymph." The chromatin composing the karyosphere is in the condition of a very fine spireme, which is so densely massed as to present the appearance under moderate magnification of a homogeneous sphere of chromatin. It is only in thin sections and with high magnification (1200 to 1800 diameters) that the spireme character is shown. Later, during the prophase, the chromosomes arise from this mass by a mere unwinding of the chromatin threads. When this process is completed nothing remains of the karyosphere but the accessory chromosome. There is apparently no nucleolar material contained in it, as no residue can be found within the nucleus and no such structure can be seen at any previous stage.

I shall now describe the changes during the same period in S. subspinipes and compare the processes in the two species. During the telophase of the last spermatogonium the appearance of the cells of the two species is identical, but at the time of the formation of the nuclear membrane the true nucleolus arises in S. subspinipes in close contact with the accessory chromosome and grows rapidly as the cell increases in size. Thus the conditions in the two species are slightly different, and it is to be expected that the subsequent behavior of the cells would also vary.

In S. heros it was impossible to follow in detail the process of the massing of the chromatin into the karyosphere. In S. subspinipes, however, this process, for reasons which I shall soon make plain, can be followed much more satisfactorily. In this species the chromatin, instead of becoming closely aggregated about the accessory chromosome, is deposited in a rather thin layer upon the periphery of the large nucleolus, or plasmosome. This structure, staining so differently from the chromatin, furnishes an excellent background, by means of which the various stages in the formation of the karyosphere may be studied with ease.

In S. subspinipes, as in S. heros, the formation of the nuclear membrane around the chromosomes may be taken as marking the transition from spermatogonium to spermatocyte. In one species, precisely as in the other, this stage ushers in a period remarkable for the concentration of the chromatin. As the cells grow the chromosomes gradually become much more diffuse and therefore stain less deeply. During this time the nucleolus, still in close apposition to the accessory chromosome (Figure 8 *b*), increases in size so rapidly that its volume is soon several times that of the accessory chromosome (Figure 8 *c*, *d*).

Shortly after the stage shown in Figure 8 *d*, the nucleolus seems also to change somewhat in its staining reaction. Irregular areas upon its periphery now show a marked affinity for chromatin stains (Figures 6, 7, 8 *e*), causing it under moderate magnification to appear of a uniform gray color.

With higher amplification, however, it is readily seen that this change is due to the deposition of some of the chromatic threads upon the surface of the nucleolus. These deposits are in the form of very diffuse spiremes, which are similar to the segments which are still free in the nuclear space (Figure 6). The nucleolus as seen in profile no longer presents an even contour, but at the places where the dark areas are found the diameter of the mass is increased (Figure 8 *e*). It is thus evident that loose threads of chromatin are being merely applied to the outside of the nucleolus, not embedded in its substance. The accessory chromosome still preserves the same relation to the nucleolus as before, being closely apposed to one side of this structure (Figure 8 *d*, *e*).

As the cell continues to grow the free chromatin within the nucleus becomes more and more scanty (Figures 6, 7), until soon only a few chromatin segments are to be seen where formerly there were many (Figure 7). Finally, in the "vesicle" stage (Figures 9–13), no chromatin is to be found in the nucleus except that which is massed about the nucleolus to form the karyosphere.

During the growth period of the spermatacyte the nucleolus has increased very markedly in size (Figure 8 *e*, *f*). This is due both to the increase of nucleolar material and to the deposition of chromatin upon the periphery of the nucleolus. At the time of the vesicle stage the appearance of the karyosphere* varies considerably in different cells, this variation being due to the different manner in which the chromatin is arranged with regard to the nucleolus. Different appearances presented by the karyosphere at this stage are shown in Figures 8 *f*, and 9–13. Usually the chromatin is distributed more or less unevenly over the surface of the nucleolus (Figures 8 *f*, 9) but often it forms a nearly complete (Figures 11, 13) or complete (Figures 10, 12) layer about it, thus causing the karyosphere to stain very intensely. In preparations stained with haemotoxylin and Congo red the karyosphere appears black when the surface is in focus, but when the centre is in focus the middle portion of the body shows a reddish-brown coloration, thus disclosing the presence of nucleolar material. Likewise, when a portion of one side of the karyosphere has been removed in the process of sectioning, the true structure of the body is shown. Figure 10, representing such a condition, shows the outer layer of intensely staining chromatin and the inner nucleolar material, containing several vacuoles.

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* In my former papers I have described the karyosphere as a highly organized structure found within the nucleus and containing "chromatin (in a granular, reticular, or spireme form), karyoplasm,—i. e., linin,—and karyolymph. It is in fact a miniature nucleus." It is now seen that it may be still more complex, since it may also contain nucleolar material.

More commonly, however, the karyosphere exhibits the reticular appearance represented in Figures 8*f*, 9. Here the chromatin is very plainly of the nature of a superficial spireme or a reticulum, which does not completely invest the nucleolus. The appearance of the karyospheres of this nature is strikingly similar to that of a small nucleus in which the chromatin is spread out over the periphery of the nuclear area in flaky masses (Figure 9).

Meanwhile the accessory chromosome has undergone no apparent change, and throughout the growth period has preserved the same relation to the nucleolus which it had during the early spermatocyte stages (Figures 5–11). Occasionally an accessory chromosome is not to be seen, owing to the fact, doubtless, that the section is cut in such a plane that the chromosome is concealed behind the karyosphere or does not lie in the same section with it (Figures 11, 12).

In S. subspinipes, just as in S. heros, a number of small granular masses of a deeply staining substance are scattered throughout the nucleus. These stain similarly to chromatin; inasmuch, however, as such masses are also present at various places in the cytoplasm outside the nucleus, it seems probable that they are not chromatin, but metaplasm — i. e., that they are either food material or by-products of the cell's activity.

In S. heros the first changes in the active prophase of the division of the first spermatocyte manifest themselves in the cytoplasmic structures; they consist in the dissolution of the archoplasm and the migration of the centrosomes. In S. subspinipes this is not true. Here the first marked change affects the chromatin. The chromosomes do not arise as distinct entities from the karyosphere by a simple disentanglement of the spireme, but the chromatic portion of the karyosphere is merely detached in the form of a varying number of flaky reticular masses, which thus come to lie free in the nuclear vesicle. These spongy masses of chromatin do not represent single chromosomes, for they later break up into several smaller masses, which soon take on the form characteristic of tetrads in the prophase. Figure 14 represents a spermatocyte in the very early prophase, in which the chromatin has just left the karyosphere. There are several chromatin masses; of these the larger one contains nearly all of the chromatin. Figures 15–18 represent slightly different stages, a little older than that shown in Figure 14. In Figure 15 the chromatin is in several masses, of which the larger ones doubtlessly represent several chromosomes. In Figures 17 and 18 the chromatin has separated into tached, leaving the nucleolus plainly visible, the conditions for observing them are favorable. At this time there are usually three or four of these vacuoles, their diameters being about one sixth to one tenth that of the plasmosome (Figures 14–18). They are clear, transparent, unstained spherules bounded by a definite outline, but enclosed in no distinguishable membrane. Later, as the prophase advances and the tetrads take on their characteristic form (Figures 19, 20), these vacuoles increase both in size and number, until, just before the nuclear membrane breaks down, they are often so numerous that the nucleolus is a spongy mass bearing little resemblance to its previous appearance. During this time the plasmosome has not appreciably altered in size; however, in the very late prophase, only a little of the original material remains.

This, I believe, might be explained on the supposition that the vacuoles represent material — probably hyaloplasm — obtained from without, while the nucleolus at the same time gives off material to the nucleus. The material thus gained by the nucleus may represent merely a by-product of cell metabolism, but the fact that the nucleolus degenerates immediately preceding cell division might be taken to indicate a more important function. Three explanations concerning the purpose and fate of the nucleolus suggest themselves: (1) the material may be used for the nutrition of the cell in general, (2) it may be used directly in the formation of the spindle fibres, or (3) it may contribute to the achromatic portion of the chromosomes. I believe that the first of these alternatives is realized in the case of S. subspinipes. In S. heros, where the archoplasmic structures are very well developed, no nucleolus is to be found at any stage of the spermatocyte. It further seems very often to be true that where the proportion of chromatin in the cell is especially large, as in the spermatocytes of insects and amphibians, no nucleolus whatever is present, thus pointing to the independence of the chromosomes. On the other hand, in cells in which there is a great preponderance of cytoplasm, as in egg cells, nucleolar structures are of very general occurrence.

The behavior of the chromosomes during the two following mitoses is so similar to that already described in S. heros that it hardly requires separate description. The result of the two spermatocyte divisions is four spermatids from each primary spermatocyte. Of these four, two contain one more chromosome each than do the other two, just as is the case in S. heros. The accessory chromosome is not divided in the first mutosis, but goes entire to one cell. In the second division, when the other chromosomes are undergoing a reduction division, this divides longitudinally. In the spermatid it is for a time distinguishable from the other chromosomes on account of its homogeneous condition.

No traces of a nucleolus are to be seen at any stage after the late prophase or early metaphase of the first spermatocyte. No such structure reappears during the short prophase of the second spermatocyte, nor have I observed it in the few spermatids to be found in my material. It would seem that, in S. subspinipes at least, the nucleolus is present only in stages of protracted mitotic inactivity.

The principal facts of interest presented in this paper are due to the presence of a true nucleolus or plasmosome in the nucleus of the sperm cells during the so-called resting stages of mitosis. The presence of this body seems to result in a considerable difference in the behavior of the chromatin and in the structure of the karyosphere. Carnoy ('85) in his "Cytodiérèse chez les arthropodes" has divided nucleolar bodies into four classes, his conclusions being based in part upon observations on the spermatogenesis of various Chilopods. These classes are as follows: "(*a*) les nucléoles nucléiniens; sperules de nucléine amorphe, ou remassée en peleton serré; (*b*) les nucléoles plasmatiques, masses albuminoides renfermant de la plastine; (*c*) les nucléoles mixtes, qui sont constitués par la réunion des deux espèces précédentes en un corps unique, où chacune se maintient cependant sous une forme figurée; (*d*) les nucléoles noyaux, ou noyaux en miniature, renfermant par conséquent tous les éléments d'un noyau véritable; membrane, portion plasmatique et portion nucléiniene.

In Lithobius, Scutigera, and Geophilus nucleoli of the fourth type, nucléoles noyaux were found by Carnoy. These are similar in general characteristics to the karyosphere in Scolopendra heros, although differing in many details. In Scolopendra dalmatica, however, according to Carnoy ('85), "L'élément nucléin d'ailleurs volumineux, est généralement irrégulier, bosseli, parfois moniliforme," and the nucleolus "n'est pas un nucléole-noyau mais un nucléole plasmatique." The structure of the nucleus "est donc celle d'un noyau ordinaire." The nucleolus does not stain with the chromatin stains and takes no part in the formation of the chromosomes, which arise directly from the chromatic network of the nucleus.

In attempting to correlate these results of Carnoy with my own observations upon American species of the same genus, one of two conclusions is necessary. Either Carnoy mistook the early prophase of the first spermatocyte for the "resting stage," or the condition of the chromatin in S. dalmatica presents yet another variation in its behavior from that found in S. heros. In the light of these later observations upon S. subspinipes, the latter view seems probable.

If Carnoy's observations be accepted as correct, we have three variations in the behavior of the chromatin during the growth period; and these variations form a graded series. In Scolopendra dalmatica the chromatin, as in the majority of metazoa, is in the form of an apparent reticulum or spireme distributed irregularly throughout the nucleus; in S. subspinipes the chromatin threads are aggregated in a rather loose manner and are deposited upon the surface of the large nucleolus, and in S. heros the chromatin filaments are so densely massed in an approximately spherical body — containing no nucleolar material — that it is only in the most favorable cases that its true spireme structure can be observed.

Zoölogical Laboratory, Harvard University,
June 14, 1905.

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EXPLANATION OF PLATE.

All drawings are of *Scolopendra subspinipes* and were made by the author from camera lucida outlines at a magnification of 1800 diameters. They were reduced one third in reproduction, making a final magnification of 1200 diameters.

FIGURE 1. Prophase of the last spermatogonial division, showing the plasmosome with the accessory chromosome closely apposed to one side, and the other chromosomes lying free in the nucleus.

FIGURES 2, 3. Early and late telophase of the last spermatogonial division. In Figure 3 the accessory chromosome can be readily distinguished from the other chromosomes, which are granular filaments.

FIGURES 4, 5. Early spermatocytes. The nuclear membrane is reappearing and the chromatin segments of the reduced number are arranged irregularly throughout the nuclear area. Evidences of the origin of the elements by an end to end union of spermatogonial chromosomes is seen in the V-shaped character of most of them. In Figure 5 the plasmosome is arising in close relation with the accessory chromosome.

FIGURE 6. A pair of spermatocytes during the growth period. The plasmosome has increased in size and some of the chromosomes have become arranged upon its periphery. Others are still free in the nucleus.

FIGURE 7. Nucleus at a slightly later stage.

FIGURE 8. Series of figures (*a-f*) showing the evolution of the plasmosome and origin of the karyosphere.

FIGURES 9–12. Various appearances presented by the karyosphere during the "vesicle" stage.

FIGURE 13. Large spermatocyte in the vesicle stage.

FIGURE 14. Early prophase of a large spermatocyte. The chromatin has become detached from the plasmosme in the form of several granular masses.

FIGURES 15–18. Nuclei in the early prophase.

FIGURE 19. Mid prophase of a large spermatocyte, showing the character of the tetrads in Scolopendra subspinipes. The nucleolus is becoming more vacuolated.

FIGURE 20. Later prophase. The tetrads have become condensed into homogeneous chromosomes, which are typically four-lobed.

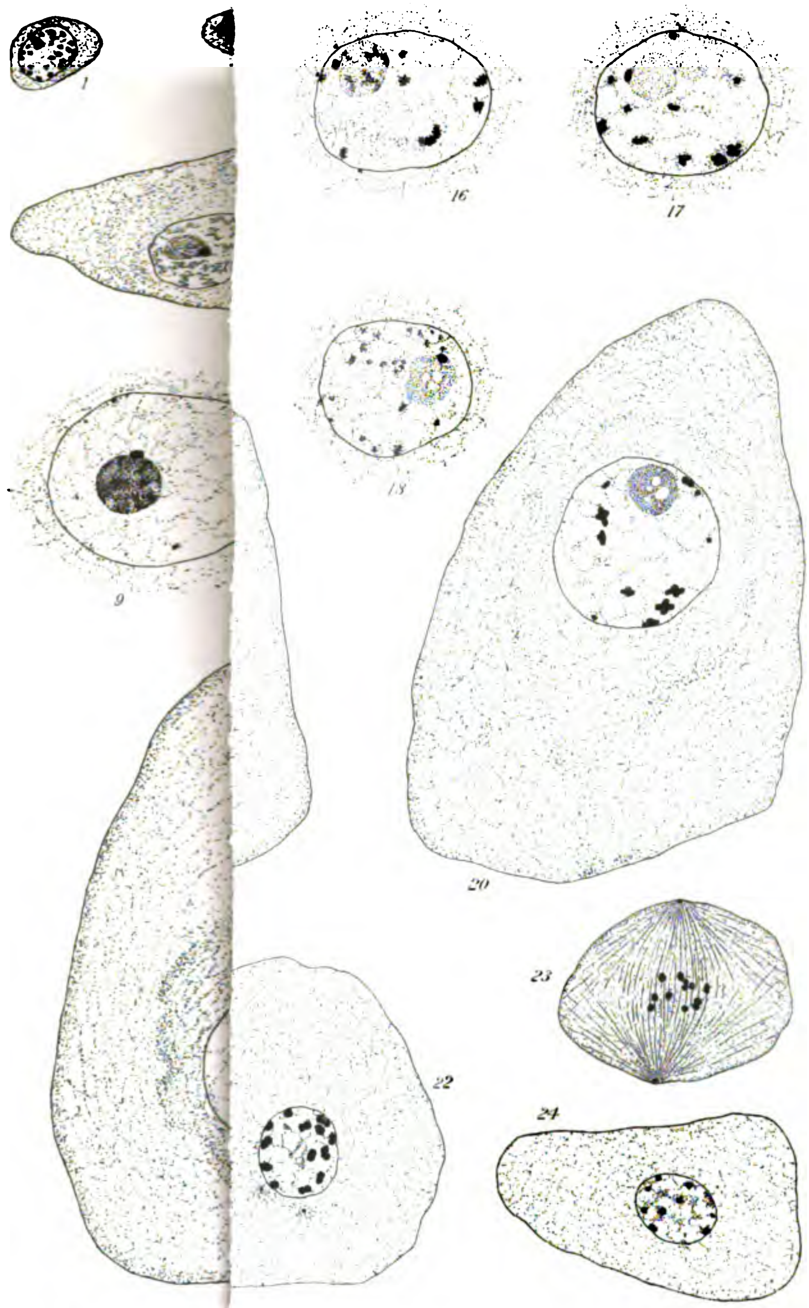
FIGURE 21. Late prophase in a small spermatocyte.

FIGURE 22. Prophase of secondary spermatocyte.

FIGURE 23. Metaphase of a small second spermatocyte.

FIGURE 24. Spermatid of Scolopendra subspinipes.

BLACKMAN.-KARYOSPHE



M. W. B. del.

B. Meisel lith.

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THE HYDROIDS OF BERMUDA.[1]

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THIS paper has for its purpose the description of certain hydroids which I collected in the summer of 1903, while an attendant at the Bermuda Biological Station. They were investigated under the guidance of Dr. C. W. Hargitt in the Zoölogical Laboratory of Syracuse University. I wish to express my great indebtedness to Dr. Hargitt for his suggestions and criticisms, and to thank the Bermuda Biological Station for courtesies extended to me during the season.

Verrill ('99, p. 571) has stated in the Proceedings of the Connecticut Academy of Science that eleven hydroids occur at Bermuda, but he does not name or describe them. I know of no other zoölogist who has occupied himself with the subject.

Of the eighteen species that were found, eight were previously undescribed. Each species which had been previously described varied in some small degree from the type individuals. The various common hydroid families are quite equally represented. *Eudendrium hargitti*, a new species, is especially interesting because of phenomena of oögenesis which have been elsewhere described (Congdon, :06). Two new species of Halecium present female gonophores whose structures are significant when compared with the gonophores of other species of the genus.

Few hydroids are found on the exposed southern shore of the Bermudas. The coves, inlets, and reefs of the opposite shore are well supplied with individuals and species. The Sargassum, which floats in after a prolonged south wind, often is the home of an abundance of *Aglaophenia minuta*, *Halecium*, and *Clytia simplex*.

Pennaria tiarella, *Eudendrium ramosum*, *Sertularia humilis*, and *Sertularella brevicyathus* are the most common species. *E. hargitti*, *Sertularella speciosa*, and *Thyroscyphus intermedius* are each confined to some single very restricted locality. In the few places especially favorable to hydroid life the strife for foothold is so marked that seven of the small species may be found growing on the larger ones.

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[1] Contributions from The Zoölogical Laboratory, Syracuse University; also Contributions from the Bermuda Biological Station for Research, No. 9.

The Bermuda hydroids show a close relationship to those of the West Indies and the Gulf of Mexico. All the genera of the new species and all but one of the species previously described are there represented. The remaining species, *Bimeria humilis*, has not to my knowledge been found south of New England.

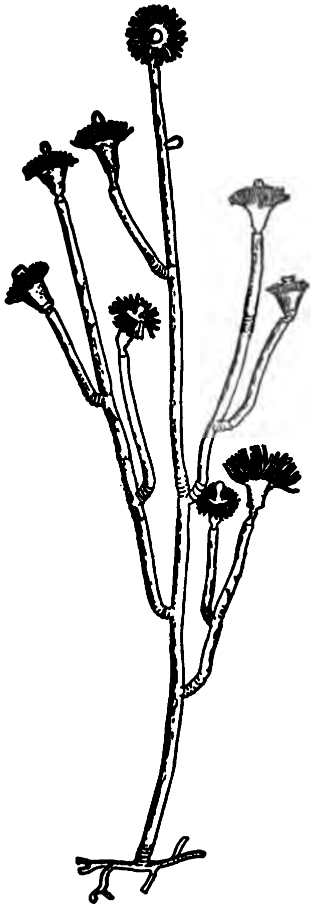


FIGURE 1. Colony of *Eudendrium hargitti* (×10).

GENUS PENNARIA McCrady.

Pennaria tiarella McCrady.

The *Pennaria tiarella* of Bermuda has on the average three more filiform tentacles than that of Wood's Hole, Mass. Clarke ('79) described a member of this genus from Cuba, under the name of *P. symmetrica*, in which the gonosome was lacking. The characters which he considers specifically distinctive are: the exact form of the hydranth, the origin of the tentacles from a little above the base, and the presence of eighteen filiform tentacles. The first two characters vary greatly with age and the amount of food in the hydranth. The number of tentacles does not seem to me of specific importance, because it varies considerably, owing only in part, I think, to the degree of maturity. It seems probable that *P. symmetrica*, like the Bermuda form, is a geographical variety of *P. tiarella*.

GENUS EUDENDRIUM Ehrenberg (in part), 1832.

Eudendrium ramosum Linnaeus.

E. ramosum differs in three respects from the individuals of Wood's Hole, Mass. There is a slightly larger average number of tentacles; there may be one more lobe to the male gonophore; the hydranth to which the clusters are attached is often entirely aborted.

Eudendrium hargitti (new species). Figures 1-5.

This hydroid was found at only one place, a shallow inlet on the south shore of Bermuda (lat. 32° 16′ 50″, long. 64° 45′ 5″). It is a handsome little form with bright reddish brown hydranths and horny brown perisarc, which contrasts with the usual substratum of white coral sand (Figure 1).

Trophosome. Stem unfascicled; colony twenty to fifty millimeters long, becoming nearly transparent toward the extremities. Branches straight, few, nearly parallel to the main stem, distributed irregularly, joining stem by an abrupt bend. Annulations at bases of colony and branches, occasionally elsewhere. Hydranth most deeply colored at base of hypostome; tentacles from thirty-five to forty-five, in contraction forming two closely appressed rows; hypostome very mobile, contracting into a shallow cup or extending to a length greater than that of the hydranth body. Some hydranths provided with a groove near the base containing gland cells and thread cells.

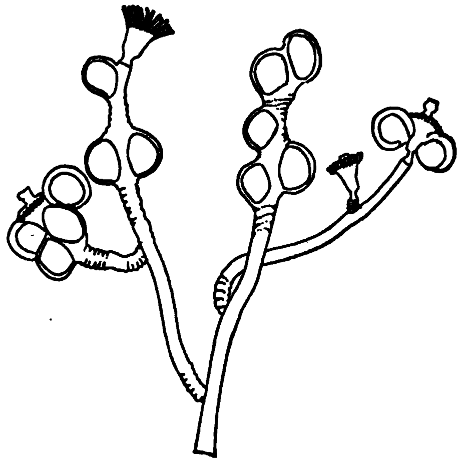
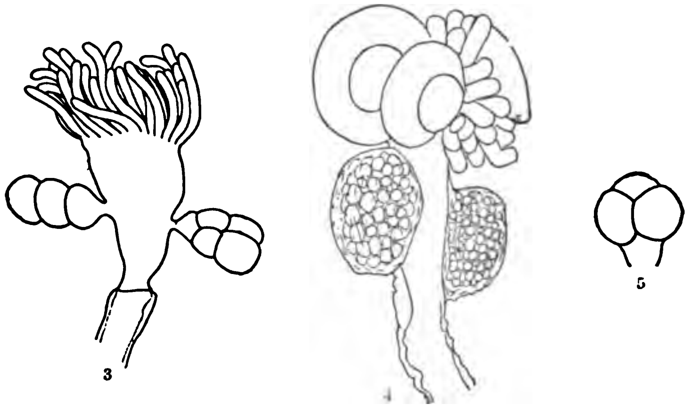


FIGURE 2. *Eudendrium hargitti.* Orthospadiceous and streptospadiceous gonophores (× 11).

Female Gonosome. Colonies dioecius. Two types of orange-colored gonophores (Figures 2, 4). One begins its development before the other, has an undivided spadix, consisting of a tube passing from the attachment upward and around the egg, and forms in conjunction with not more than four others a circle around the base of the hydranth body. The gonosomes of the second type are associated in clusters of two to seven closely and rather irregularly around a thick finely annulated pedicel, which may or may not have a terminal hydranth. They are partly confluent with the stem, ovoid, completely invested on the exposed side by a spadix, often indistinctly separated into a proximal and a distal group. A dozen clusters may occur close together on a basal branch. Found toward the base of the colony always below the first type, whether occupying the same stem or not. A pedicel bearing this type may support a hydranth upon which the other type occurs.

Male Gonosome. Gonophores on an aborted hydranth and much annulated pedicel (Figures 3, 5). Three-chambered in a moniliform arrangement (Figure 3, left side) with but slight constriction between the lobes and their relative diameter variable. Four lobes may be arranged so as to form a diamond-shaped cluster, or another may be added proximally upon one side (Figure 3, right side).



FIGURES 3–5. *Eudendrium hargitti.*

FIGURE 3. Hydranth with common type of male gonophore to the left and a less common form to the right (× 26).

FIGURE 4. Distal streptospadiceous and proximal orthospadiceous gonophores (× 12).

FIGURE 5. An unusual form of male gonophore (× 22).

The variability and simplicity of these gonophores in comparison with other Eudendria is suggestive of degeneration. This hydroid has the distinction of being the only member of the genus whose egg is known to grow by the absorption of other cells.

It is a pleasure to name this species after Professor Charles W. Hargitt. To those who, as students of the Hydromedusae, are acquainted with his various contributions relating to problems of the group, the reason for so doing is apparent.

GENUS BIMERIA S. Wright, 1859.

Bimeria humilis Allman. Figure 6.

Dense growths of the colonies of this small animal are to be found on Eudendrium, Pennaria, sponges, and the like. The stem of Pennaria often forms the centre of a cylindrical mass a centimeter in diameter. No gonosome is present.

The genus Bimeria was established in 1859 by Strethill Wright for a hydroid of the Firth of Forth, characterized by a covering of perisarc on the hydranth body and around the bases of the tentacles (Allman, '71, p. 297). Allman ('77, p. 8) added to the genus the species *B. humilis* from the Tortugas, which differs but slightly from the Bermuda Bimeria.

Gonosome is lacking. In two respects the hydroids differ. The Tortugas form has a very opaque perisarc as described by Allman; in the Bermuda form it is transparent; but descriptions of other species added to the genus later by different authors suggest by their dissimilarity that in regard to this character individuals may vary in appearance. Secondly, Allman states that he was not able to detect the ends of the tentacle tubes and his figures do not show them. By focussing on the end of an expanded hydranth, I had no difficulty in finding them. There is thus no warrant for constituting a new species unless the gonosomes reveal differences.

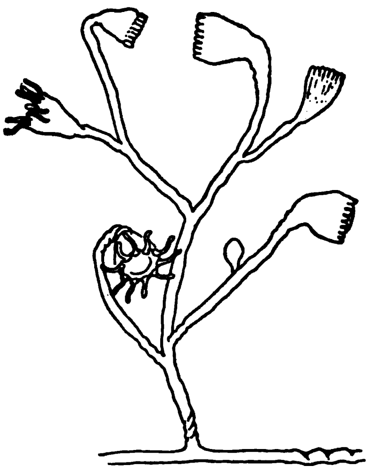


FIGURE 6. Colony of *Bimeria humilis* (× 18).

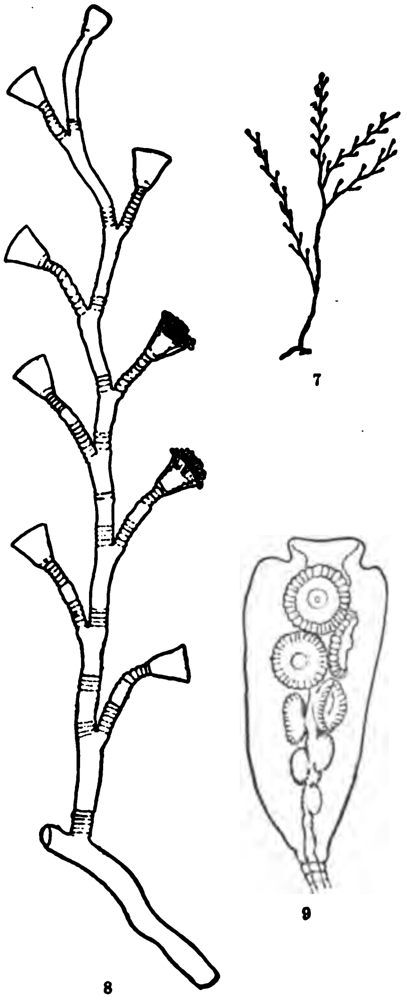
GENUS LAFOEA Lamouroux, 1812.

Lafoea calcarata A. Agassiz.

A small number of colonies were found growing around the base of a hydroid. Unfortunately the collection was lost before it could be examined at length.

GENUS OBELIA Peron and Leseur, 1809.

Obelia hyalina S. F. Clarke. Figures 7–9.



FIGURES 7–9. *Obelia hyalina.*

FIGURE 7. Colony (× 8).
FIGURE 8. Colony (× 30).
FIGURE 9. Gonotheca (× 60).

Obelia hyalina grows on sponges, algae, and large hydroids which inhabit the shallow waters of Bermuda (Figures 7, 8). Stems and branches may develop short stolons. The branches are described by Clarke as arising from the axils of hydrothecae. I found them more commonly resulting from the extension of pedicels. The gonothecae which Clarke found were evidently immature, since they are figured with a truncate end. Later these develop a small aperture surrounded by a flaring rim (Figure 9).

GENUS CAMPANULARIA
Lamouroux (in part) 1816.

Campanularia insignis
Allman. Figures 10–12.

The animal lives in all the localities along the shores of Bermuda where hydroids are plentiful. The trophosome (Figure 10) was described by Allman from a dredging of the Challenger expedition in thirty fathoms of water off the coast of Bermuda. I have to add a description of the gonosome.

An interesting character not to my knowledge elsewhere found in the genus Campanularia, is the vegetative reproduction through the agency of stolons, much as takes place in plants by creepers

(Figure 11). The outgrowths arise from the ends of the stems and branches or may replace the latter. They are present in colonies of all sizes and are most abundant at the distal end. By their elongation, sometimes aided by a bending of the colony, their tips come in contact with the substratum. A clump of rhizoids forms and a new colony rises from them. Only a small proportion of the stolons were engaged in this process. Hincks ('68, p. 170) figures similar stolons on *C. angulata*, but they were not seen to give rise to colonies.

Nutting (:00, p. 44) has seen a species of Aglaophenia in the act of conjugating by means of stolons. A hooked stolon of one colony catches a similar structure of another. Fusion occurs, and after a resting period of three months a colony arises at the point of contact.

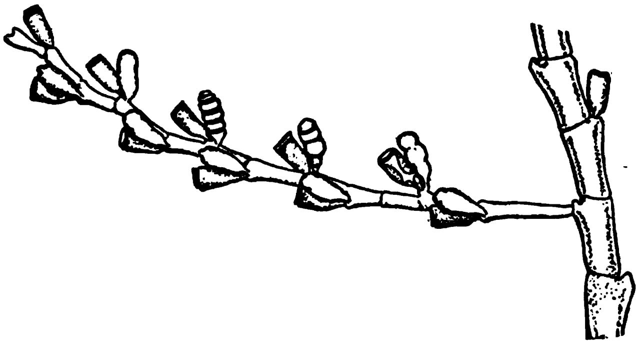


FIGURE 10. *Campanularia insignis.* Branch and part of main stem, showing two types of gonophores (× 4).

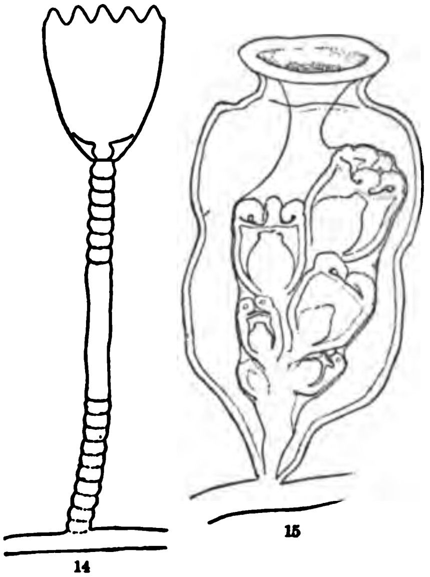
Though I found no case of fusion in many hundred colonies, the possibility of its occurrence is suggested by the hooked ends of the young stolons. Sometimes a small hooked stolon arises perpendicularly from near the end of another. As the branches grow larger, the hook gradually straightens, until there is but a slight curve, as found in *C. angulata*, *S. pumila*, and other species.

Gonosome. I found two types of gonothecae. The one was cylindrical and divided into about five lobes by regular and broad furrows (Figures 10, 12). It was not apparent from their structure whether they were female or immature male gonothecae, and I was not able to investigate their histology. The other form was ovoid with a constricted opening and a single male gonophore (Figure 10).

The spermatozoa develop in gonothecae instead of in medusae. A thick layer of sperm mother-cells lies next the mesogloea in the entoderm.

Trophosome. Minute white colonies, seldom ten millimeters long, arising rather sparsely from a creeping stolon, bearing a deeply campanulate hydrotheca, pedicel annulated most commonly at both ends, (Figure 14), hydrothecae only one and one-third to twice as long as wide, the proportion depending on the age and condition of expansion of hydranth. Ten to twelve triangular teeth, more or less rounded and of varying proportions. Wall of hydrotheca thickened below hydranth to form a spheroidal cavity. Hydranth of usual type with twenty to twenty-four tentacles.

Gonosome. Gonothecae arising from stolons, sessile, twice as long as hydrothecae, ovoid and flattened, distal end truncate and flaring, and of one half to two thirds the diameter of the gonothecae (Figure 15). About eight medusa buds are attached along the blastostyle, of which the most mature are campanulate in form with four tentacles and four other rudimentary organs interradial in position. The manubrium may occupy half the space within the bell, is nearly spherical, and apparently not provided with any terminal lobes.



FIGURES 14, 15. *Clytia simplex.*
FIGURE 14. An individual (× 18).
FIGURE 15. Gonotheca (× 60).

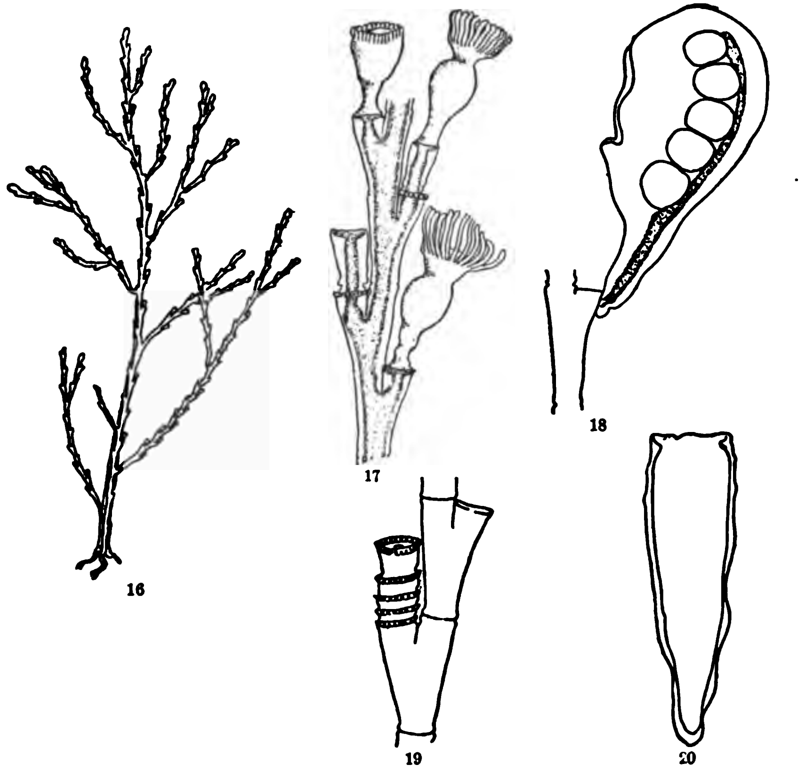
This Clytia combines the unbranched habit of *C. bicophora* and *C. grayi* with the non-annulated or weakly annulated gonosome of *C. cylindrica.* The teeth of the hydrothecae are less pointed than those of *C. bicophora*, and, though as rounded as those of *C. grayi*, are much more deeply cut. The specific name "simplex" is suggested by the marked simplicity in the form of trophosome and gonosome.

GENUS HALECIUM Oken, 1815.

Halecium bermudense (new species). Figures 16–20.

The hydroid occurs in those places along the shores of Bermuda which are most frequented by related species.

Trophosome. Colonies delicate and graceful, with hyaline or brownish perisarc, usually twenty to thirty-five millimeters long, main stem and large branches fascicled in part, elsewhere slightly geniculate (Figures 16, 17). Branches irregularly placed, arising from below hydrophores, when young, by an abrupt curve, which later is less apparent; occasionally, toward the end of larger branches, arising midway between hydrophores. Branches may twice subdivide. They tend to form a cluster at the tip of the colony.



FIGURES 16–20. *Halecium bermudense.*

FIGURE 16. Colony (× 4).
FIGURE 17. Part of a colony (× 24).
FIGURE 18. Female gonotheca (× 27).
FIGURE 19. Compound hydrophore (× 30).
FIGURE 20. Male gonotheca (× 27).

Hydrophores alternate, very shallow, with usual ring of refractile phore in any way similar to this. It falls in a natural group with the other species here described, *H. beanii*, *H. dichotomum*, *H. sessile*, and *H. bermudense*, because all have large hydranths, shallow hydrophores, and slipper-shaped female gonothecae. It is of interest for purposes of comparison to arrange the salient characters of the female gonophores of these forms in an order suggested by their structure.

H. marki. Female gonotheca has two tubes, each bearing a hydranth, which reach from the centre of the gonophore to its summit. The opening is at the summit.

H. beanii. Tubes much shortened and mouth at top on a level with the tubes.

H. dichotomum. Only one tube springing from the side half-way down.

H. sessile. Like *H. bermudense*, but the opening at top and the remains of tube gone.

Though recognizing that caution should be used in formulating theories as to the development of animal structures from such comparisons as are suggested above, it seems to me that the facts point forcibly to the origin of the slipper-shaped gonotheca in the following way. The gonotheca structure in the present species suggests that a hydrophore bearing a gonotheca also gave rise to a branch on either side, the latter a common condition in the species. The two branches with their terminal hydranths then became fused with the gonotheca. In this species the fusion is complete half-way up the gonotheca. Next the tubes shortened further by a contraction of their upper part until they became mere openings and the aperture of the gonotheca remained near to them, as in *H. macrocephalum*. In *H. bermudense* the opening is elongated toward the top. *H. sessile* and others have the opening at the top, but retain the slipper-like form.

GENUS SERTULARELLA Gray (modified), 1847.

Sertularella speciosa (new species). Figures 24-28.

This form was found only at the opening of an underground passage connecting Harrington Sound and Castle Harbor (lat. 32°20′ 30″, long. 64°42′ 10″).

Trophosome. Colonies fascicled, truncate, usually five to eight inches high (Figures 24, 28). Occasionally a large branch occurs resembling the main colony. Pinnae alternate, making an angle of eighty degrees with the stem, divided into nodes at intervals of some five hydrothecae by grooves slanting alternately in opposite directions. Stolons occur at ends of stems and branches.

Hydrothecae alternate, embedded in stem or pinna nearly to the opening, separated by a considerable space from each other, cylindrical and flattened laterally, the lower end tapering slightly, with no line marking its union below and no diaphragm, the upper end bending out at an angle of sixty degrees. The hydrothecae of the branches grow from a pair of tubes on opposite sides of the stem. There are usually three between successive pinnae on one side, one of which is just above the origin.

The opercula of young hydrothecae have four, or occasionally five, ridges, terminating in corresponding projections of the edge; one abcauline, and the others symmetrically placed. Operculum usually first ruptured at centre. Four ragged lobes or a rim may remain until maturity, but they are more commonly lost. Projections usually persist, becoming less distinct. Two or three rings usually found below the edge of old hydrothecae.

Expanded hydranths trumpet shaped, hypostome conical, tentacles twenty to thirty. A blind sack is attached to abcauline wall of hydrotheca, from which projects a transverse edge.

Gonosome. Colonies dioecious. Male and female gonothecae, arising from pinnae, externally similar, equal to five hydrothecae in length (Figure 26). Theca hyaline, cylindrical, distally truncate, proximally constricted for one fourth its length into a pedicel-like base. Axis slightly curving, markings of surface often very faint, consisting of eleven longitudinal ridges terminating in lobes along the distal margin, separated by more faint parallel ridges and six or eight broad shallow circular

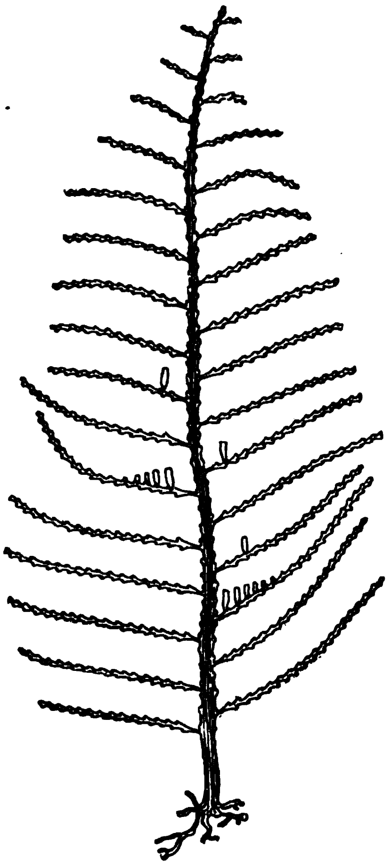
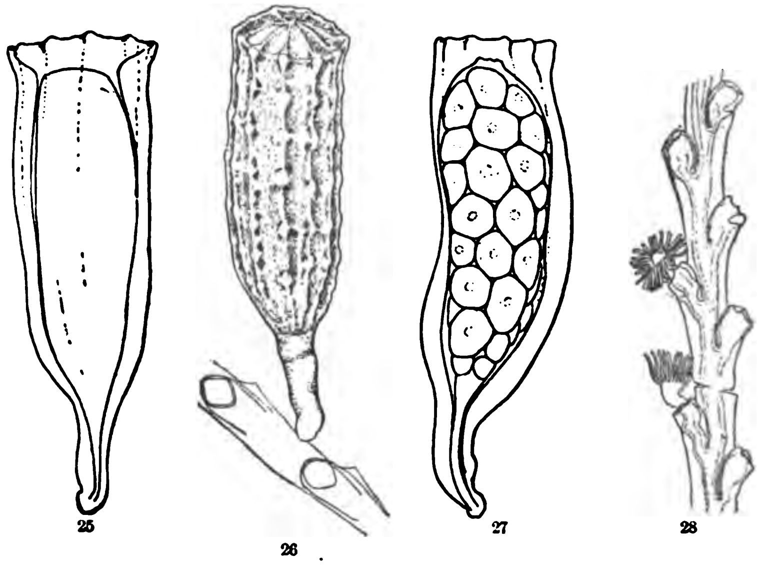


FIGURE 24. *Sertularella speciosa.* Colony with gonothecae (× 1½).

grooves. Top has radial ridges terminating in the lobes. Gonothecae attached below hydrothecae, one or two near base of branches, or a series decreasing in size distally or otherwise arranged. Female gonothecae with gonophores filling the cavity containing about forty eggs arranged around a lumen (Figure 27). The male gonothecae similar (Figure 25).

I examined the structure of the stem by macerating it in caustic potash. Twenty tubes occur near the base of a small colony and four near the top. They extend for various distances upward to terminate by joining others. The rhizoids consist of tubes which themselves unite near the base of the colony much as do the former. In each colony there is one large hydrothecae-bearing tube which gives rise to the pinnae of one side near the base and further up for both sides. It arises from a union of other tubes near the base of the colony and traverses the entire stem. Pinnae on the side opposite the large tube arise from tubes which become hydrothecae-bearing for a short distance, give off two or three other branches, and then terminate in a tapering

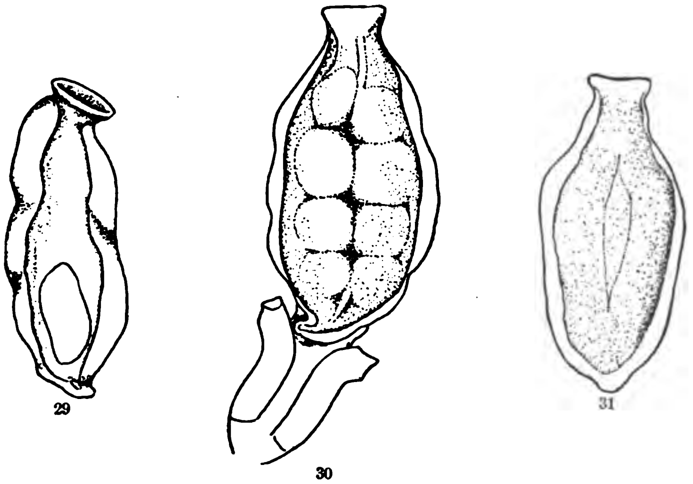


FIGURES 25–28. *Sertularella speciosa.*

FIGURE 25. Male gonotheca (× 30).
FIGURE 26. Female gonotheca (× 30).
FIGURE 27. Female gonotheca (× 30).
FIGURE 28. Part of branch (× 22).

process which joins another tube of similar structure. The large tube and all hydrothecae-bearing tubes are segmented, as well as the others, just before uniting with them.

The present species is an illustration of the difficulty which is found in delimiting the genus Sertularia and some other genera of the same family. The genus is confined by Nutting (: 04, p. 37) to those species in which the operculum is well defined or stretched tightly over the top of the hydrotheca. Though neither condition occurs here, the characters of hypostome and gonosome place the species unmistakably in this genus. *Thuiaria pinnata*, described by Allman from the Double-headed Shot Key, is similar in trophosome, but the hydrothecae are less confluent (Allman, '77, p. 28). The gonosome is not known. *Sertularella distans* is also much like this species (Nutting, : 04, p. 88). The stem is, however, unfascicled and the hydrothecae provided with a constant border.



FIGURES 29–31. *Sertularella humilis.*

FIGURE 29. Female gonotheca, one egg remaining (× 25).
FIGURE 30. Female gonotheca, eggs not discharged (× 25).
FIGURE 31. Male gonotheca (× 25).

GENUS SERTULARIA Linnaeus (in part), 1767.

Sertularia humilis (new species). Figures 29–32.

This is one of the hydroids most common at Bermuda. It grows so abundantly between tide marks as to make thick brown mats, which frequently contain coral mud and diatoms. Doubtless it is protected at low tide by its denseness, which mitigates desiccation. The name refers to its humble appearance.

Trophosome. Colonies are a deep horn color, pinnate, unfascicled, thirty to forty millimeters long. The sometimes geniculate stem is constricted below each of the ten or more alternate pinnae (Figure 32).

Three sessile hydrothecae usually found on each joint of stem, most frequently two on the same side as the pinna, the other sub-opposite the more distal. Variations in arrangement are found, such as two pairs of opposite hydrothecae on a joint. The flattened pinnae with two or three pairs of opposite, or slightly sub-opposite, hydrothecae to a segment. Base of stem and pinnae devoid of hydrothecae.

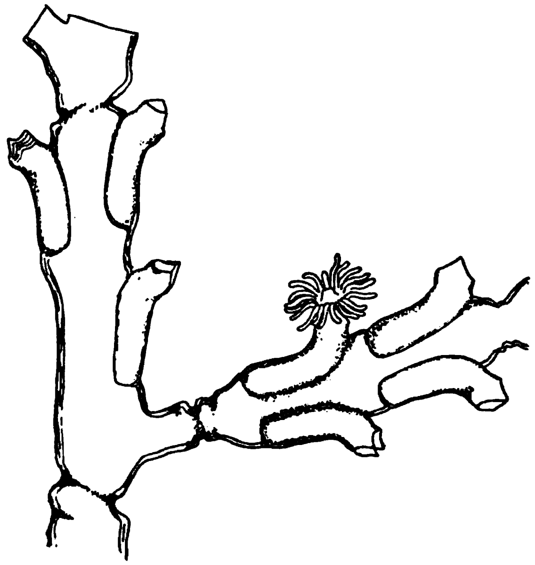


FIGURE 32. *Sertularella humilis.* Part of main stem and branch (× 25).

Hydrothecae of stem and pinnae tubular and two or three times as long as wide for the lower two thirds of their length, and at the base confluent with the stem. Above, bending outward at an angle of thirty-five to forty-five degrees, and also slightly toward each other. On this side the intervening space usually not so wide as a hydrotheca, though width increases with age. Outer border of hydrotheca continuous with border of stem or pinna, which extends proximally for a short distance to the next hydrotheca or constriction. The confluent portion of the hydrotheca diverges from the axis to a small degree, distally. There is a proximal diaphragm.

Edge of hydrotheca provided with a single adcauline and abcauline scallop, each of which is marked by a slight projection at its centre. In older hydrothecae several parallel ridges near the edge and operculum may be largely torn away; in younger consisting of three parts, meeting in ridges extending from the centre to the three projections. A lateral view of the colony presents the edge of many opercula, but shows the upper valve of some.

Gonosome. Colonies dioecious. Form of gonotheca the same in both sexes (Figures 29–31), more than twice as long as hydrothecae, ovoid, with a flaring mouth. They are most abundant in proximal part of colony, attached to hydrothecae just below diaphragm. A gonotheca was once observed rising from the interior of a hydrotheca. Characteristic markings may have been lost as the gonothecae were not well preserved. About sixteen eggs in the single large gonophore (Figure 30). Male gonothecae of similar appearance.

Sertularia brevicyathus Versluys.

So prolific is this little animal in some places that one can hardly pick up a piece of sponge, seaweed, or large hydroid without finding a dense growth attached.

Versluys ('99, p. 40) first described it from the Cape Verde Islands, and later Nutting (:04, p. 60) from the Bahamas. Neither author came upon the rather infrequent branches, which are attached at an acute angle just below the hydrothecae and differ in no respect from colonies.

Stolons are not uncommon. They may be given off like branches or from the tip of the colony. In the latter case they are often as long as a colony. If a number occur in one colony, they are arranged in pairs or are irregularly distributed.

The gonosome has not been previously described. Gonothecae are usually solitary on a colony, and attached just below a basal hydrotheca. Both male and female gonothecae are sessile, with a constricted opening, a low flaring lip, and wavy surface. They are closely similar to the gonothecae of *S. pumila*. These have been so completely described by Weismann as to render further account unnecessary.

Sertularia versluysi Nutting.

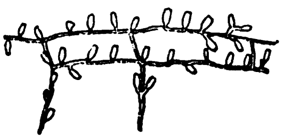
Sertularia versluysi was first described by Allman from dredgings off the coast of Bermuda in thirty fathoms. I have only a few colonies, which I found on floating Sargassum.

Versluys believed the animal had an operculum with a single abcauline flap. Nutting (: 04, p. 53) was inclined to think there were two flaps on his badly ruptured specimen. Material in good condition shows that there are two large lateral projections from the edge of the hydrotheca and a smaller adcauline one. The three parts of the operculum meet in ridges along lines passing from the centre of the opening to the projecting points.

GENUS THYROSCYPHUS Allman, 1877.

Thyrocyphus intermedius (new species). **Figures 33–36.**

My only collection of this new form is from the eel grass of a shallow, muddy cove of Mangrove Bay (lat. 32° 18′ 10″, long. 64° 51′ 30″). Hydrothecae usually single, with pedicels one and a half millimeters long (Figure 36). A small proportion have two or three hydrothecae, whose annulated, geniculate, erect stems resemble elongated stolons (Figure 35). A terminal hydrotheca is found at one end of the axis and one or two others are attached at geniculations. The annulated pedicels are shorter than hydrothecae; when single, not more than a third as long.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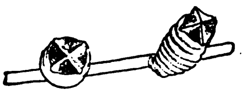
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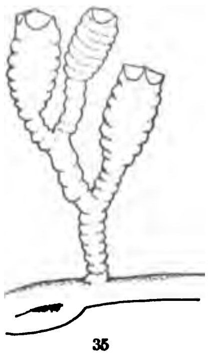
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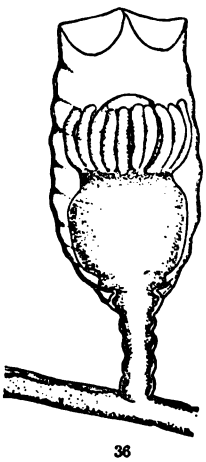
36

FIGURES 33-36. *Thyroscyphus intermedius.*

FIGURE 33. Colony (× 1½).
FIGURE 34. Hydranths, showing operculum (×7½)
FIGURE 35. Colony (× 10).
FIGURE 36. Hydranth (× 60).

Hydrothecae (Figure 36) are more than twice as long as wide, nearly cylindrical, marked by eight or more annulations, and tapering slightly toward the top. An operculum is formed by the bending of the hydrotheca wall to form four deep symmetrical scallops. The edges meet in two deep intersecting ridges, which terminate at the four points between the scallops (Figure 34). The narrow diaphragm consists of a fold which encloses a considerable space.

Colonies arise from creeping stolons, which are as large as a pedicel and not annulated (Figure 33). They grow parallel to each other along the blades of eel grass, sending frequent connecting branches across to neighboring stolons.

The few well-preserved hydranths are contracted into the lower half of the hydrotheca. They are attached to the diaphragm only, possibly because of unsatisfactory killing. There are about twenty tentacles and the hypostome is rounded.

The characters of the trophosome are allied to both Campanularidae and Sertularidae. The occurrence of diaphragm, pedicel, and an ovato-cylindrical annulated hydrotheca suggest the former. Yet we do not find a four-part operculum in that family except in the genus Thyroscyphus, erected by Allman in 1877 for the single species *T. ramosus*, which is of doubtful affinity (Nutting, :04, p. 10). The jointed stem, shortness of pedicel, and four-part operculum suggest its close relation with the genus Sertularella. If the gonosome is of the Sertularella type, the existence of a pedicel would be the only character separating it from that genus.

The genus Sertularella as revised by Hartlaub contains species with a hydrotheca and operculum closely similar to the Bermuda hydroid. The one character in which it differs from the genus is the presence of a pedicel. This difference Allman judged so important in the case of *T. ramosus* as to demand a new genus. I have accepted his view of the matter.

The chief differences between the two species, as far as we now know, are these: *T. ramosus* is larger, has a bordered hydrotheca, and a jointed stem bearing many hydrothecae instead of a short, annulated, unjointed one bearing at most three hydrothecae.

GENUS AGLAOPHENIA Lamouroux, 1816.

Aglaophenia minuta Fewkes. Figure 37.

This form is rather widely distributed. It occurs on the Sargassum, which drifts to Bermuda from the south. Though I did not find the gonosome, the complex trophosome was sufficient for identification. A small nematophore is always present on each side of the axil of a branch. The fact is not mentioned by Fewkes nor in the fuller description by Nutting.

GENUS LYTOCARPUS Kirchenpauer, 1872. Figure 37.

Lytocarpus philippinus Kirchenpauer.

Lytocarpus philippinus is found at the places where hydroids most abound along the shores of Bermuda. It was also dredged from the Challenger banks, south of Bermuda. It was first described by Kirchenpauer from the Philippine Islands, and since has been noted from many stations in the Pacific and from Jamaica.

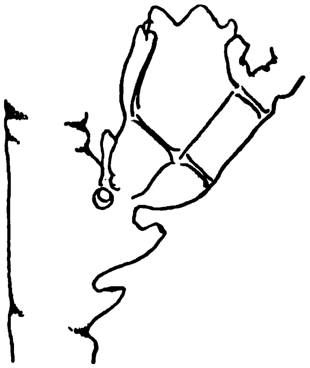

FIGURE 37.
Lytocarpus philippinus. Base of pinna (× 105).

The following slight variations from the description and plate of Nutting are to be found: the mesial nematophore is longer; the intrathecal ridge nearer the base, and the colony shorter.

GENUS PLUMULARIA Lamarck, 1815, modified by Nutting, 1900.

Plumularia alternata Nutting.

Nutting has described this form from a collection made by Agassiz at Barracuda Rocks during the cruise of the "Wild Duck" in 1893. I found it to be one of the less common hydroids growing upon the floating Sargassum in the vicinity of Bermuda. The gonosome is not known.

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July, 1906.

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CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL STATION
FOR RESEARCH.

No. 10.

THE SPERMATOGENESIS OF THE MYRIAPODS.
V. ON THE SPERMATOGENESIS OF LITHOBIUS.

By Maulsby W. Blackman.

With Two Plates.

From the Proceedings of the American Academy of
Arts and Sciences, Vol. XLII., No. 19.

CAMBRIDGE, MASS., U. S. A.
February, 1907.

THE SPERMATOGENESIS OF THE MYRIAPODS.

V.—ON THE SPERMATOCYTES OF LITHOBIUS.[1]

By Maulsby W. Blackman.

Presented by E. L. Mark, December 12, 1906. Received November 22, 1906.

For a number of years the author has been collecting material for a comparative study of the spermatogenesis of the principal groups of the Chilopoda. Five papers based upon this material have already been published; a series of four papers (Blackman, :01, :03, :05, :05^{a}) upon two species of Scolopendra (S. heros and S. subspinipes) and one paper upon Scutigera forceps by Medes (:05). In the present article it is my purpose to carry this comparative study further.

The present paper is based upon a study of the spermatocytes in three species of the genus Lithobius and is from material collected in three widely separated localities. The principal observations were made on the testes of Lithobius mordax, collected in the vicinity of Lawrence, Kansas, during the spring and summer of 1902 and 1903. Using as a basis the knowledge gained from the study of this species, additional observations have been made upon Lithobius sp.? and Lithobius multidentatus, with a view to comparison. The material of Lithobius sp.? was collected by the author near Flatts, Bermuda, during July, 1903, while working at the Bermuda Biological Station for Research; that of Lithobius multidentatus was collected near Cambridge, Mass., during October, 1904.

At the time this comparative study of myriapod spermatogenesis was begun, no detailed work upon the germ cells of chilopods had been attempted under modern conditions of technique. The only observations upon this material then published were those of Carnoy ('85) in his classical Cytodierèse chez les arthropodes, and those of Prenant ('87, '92). Since then, however, a number of papers based upon the sperm cells of myriapods have appeared. Of those dealing with problems touched upon in this article the chief are those by Meves and von Korff (Lithobius forficatus), :01; P. Bouin, :00, :01, :03, :03ᵃ, :04; P. et M. Bouin, :02, Lithobius forficatus and Scolopendra morsitans; P. Bouin et R. Collin, :01, Geophilus linearis.

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[1] Contributions from the Bermuda Biological Station for Research, No. 10; and from the Laboratory of Histology and Embryology, Western Reserve University.

The results obtained by these authors differ so markedly in several important particulars from those obtained by myself (Blackman, :01, :03, :05, :05ᵃ) on Scolopendra and by Medes (:05) on Scutigera that it seemed advisable to extend the comparative study to the genera upon which they had worked. What I consider the important discrepancies between the observations upon American and those upon European forms have to do with the condition of the chromatin during the growth period and its later behavior in the prophase. According to my observations upon the two species of Scolopendra, the chromatin during the growth period is not arranged in the form of a spireme, or reticulum, throughout the nucleus, but the threads are aggregated into a very dense mass, the karyosphere, and at the beginning of the prophase the chromosomes arise from this mass directly. The observations of Medes (:05) show that an essentially similar condition exists in Scutigera. All the observations upon the European forms, however, except the early ones of Carnoy ('85) upon Lithobius and Scutigera, seem to lead to the conclusion that the large intra-nuclear bodies seen in all chilopod spermatocytes are true nucleoli and have no genetic relation to the prophase chromosomes. As will be seen later in this paper, my present observations on Lithobius confirm my earlier ones on Scolopendra.

TECHNIQUE.

In the preparation of the material much difficulty was at first experienced in obtaining a good fixation of all the cell structures, owing to the peculiar character of the cytoplasm. Thus, in the early study, a large number of fixing reagents were used, including the following: Flemming's strong solution, Flemming's weak solution, Gilson's fluid, Perenyi's fluid, Merkel's fluid, and various picro-acetic and sublimate-acetic mixtures. Of these, much the best results were obtained with Gilson's nitric-acetic-sublimate mixture. While the results of this fixation were not always entirely satisfactory, the majority of preparations thus obtained apparently left nothing to be desired. In later studies Bouin's picric-acetic-formol mixture was tried, but the results were much inferior to those obtained with Gilson's fluid.

The sections were cut with the Minot rotary microtome, the thickness varying from 2 to 6 micra, and were affixed to the slide by means of very dilute albumen water. The sections were then stained by one or another of a number of methods, the best cytological results being obtained with Heidenhain's haemotoxylin used either alone or with Congo red as a counterstain. Sections thus stained were used for all detailed studies of the cell structures. For micro-chemical tests, Flemming's three-color stain and the Ehrlich-Biondi mixture were used, the results obtained with the latter being especially satisfactory.

OBSERVATIONS.

The testis of Lithobius consists of a single unpaired sac tapering at the anterior end, where it ends blindly, and also tapering slightly at the posterior end, where it is directly continuous with the vas deferens. In adults, which were used exclusively in this study, the spermatogonia are found only at the periphery of the testes. They are small spindle-shaped cells containing oval nuclei (Plate 1, Figure 1), and are similar in all respects to the spermatogonia of Scolopendra, with the exception that each nucleus contains two karyospheres instead of one. These karyospheres consist largely of chromatin, as is shown by their reaction to stains. They are stained black in iron-haemotoxylin, and after treatment with the Ehrlich-Biondi mixture they are colored green, while all other cell structures assume a red tint. The remaining portion of the nucleus is occupied by a network of linin fibres, which stains as lightly as does the cytoplasm outside of the nucleus.

The constancy with which two karyospheres, and never more than two, occur in the spermatogonia of Lithobius mordax has led me to ask what significance this may have. When we consider that there are always two karyospheres in the spermatogonia, and never more than one in the spermatocytes of this species, the explanation suggests itself that one of the spermatogonial karyospheres may represent the chromosome group derived from the mother, while the other one is made up of paternal chromosomes. However, it would seem impossible to obtain proof of this, and the suggestion is made merely as an interesting possibility. Furthermore, this condition is constant only for Lithobius mordax, while in Lithobius sp.? the number of karyospheres in the spermatocytes is often as great as four. At the beginning of the active prophase of the spermatogonial mitoses in Lithobius, the chromatin leaves the karyospheres and becomes arranged throughout the nucleus in the form of a large number of fine granular threads (Figure 2), each one of which represents a chromosome. The number of these segments at this stage is so great, and the nucleus is so small, that it has been found impossible to count them; but from counts of the chromosomes during the spermatocyte stages, it may be inferred that the number of these granular threads found in the spermatogonia is forty-eight, so that with the accessory chromosome the total spermatogonial number is forty-nine.

After the origin of the chromatin segments from the karyospheres the residue consists of two sorts of material: a small, deeply staining body, the accessory chromosome, and two lightly staining plasmosomes (Figure 2). The plasmosomes remain in the nucleus during the prophase, and are dissolved at the time of the breaking down of the nuclear membrane. The accessory chromosome is usually closely applied to one of these nucleoli, although it may be entirely free from both.

Thus the conditions at this time are quite similar to those found in Scolopendra subspinipes (Blackman, :05[a]), where a portion of the residue of the karyosphere is nucleolar material, while the other portion is a modified chromosome. In Scolopendra heros, on the contrary, all the products of the karyosphere are chromatic. One point of difference, however, between the spermatogonial prophases in Lithobius on the one hand, and in the two species of Scolopendra (Blackman, :03, :05[a]) and in Scutigera forceps (Medes, :05) on the other, is the shape and appearance of the chromosomes. In Lithobius these elements are slender granular segments, similar to the corresponding structures in insect spermatogonia, while in the other three species mentioned the chromosomes are in the form of small rounded granular masses, which never lengthen out to form threads. The later stages of the spermatogonial mitosis offer no points of especial interest, and will not be described in this paper.

The telophase stages of the last spermatogonial division are similar in all essential respects to those in Scolopendra and Scutigera. The daughter chromosomes, as they move toward opposite poles of the spindle, are aggregated into dense masses. At this stage the chromosomes are rounded bodies possessing clear-cut outlines. Soon, however, just as in Scolopendra, they begin to lengthen out and become granular, and thus in place of a mass of closely aggregated homogeneous bodies there soon arises a more loosely arranged group of granular segments. At first this is enclosed in no membrane, but lies within a vacuole of hyaloplasm. Eventually, however, a definite nuclear membrane appears and the chromatin segments become distributed throughout the space enclosed by it (Figures 3, 4). It may now be readily seen that the number of these chromatin segments is much smaller than the number of chromosomes seen during the spermatogonial prophase. Careful counts give the number of segments at this stage as 24, which, together with the accessory chromosome, produces a total of 25, the number of chromosomes characteristic of the following mitosis. Thus here, just as in Scolopendra, pseudo-reduction has already occurred as the result of the union in pairs of the spermatogonial chromosomes during the telophase of the last mitosis of the division period.

Evidences of the nature of this union are to be seen in many nuclei, although, owing to the close grouping of the chromosomes in the telophase, actual stages in the union are very difficult to find. In the two species of Scolopendra (Blackman, :03, :05, :05^{a}) it has been shown that this union of the chromosomes is accomplished by an end to end fusion of the elements, similar to that described by Montgomery (:00, :01) for Peripatus, and by Sutton (:02) for Brachystola. In the three species of Lithobius studied, evidences of the origin of the spermatocyte chromosomes by a similar union are seen in Figures 3 and 4. The chromatin segments are often bent at a sharp angle at about their middle point, the two equal limbs representing spermatogonial chromosomes which have conjugated during the preceding telophase. Thus in Lithobius, just as in Scolopendra and in Scutigera, there is no stage in which all of the chromatin is arranged in a continuous spireme, and at no time is the number of chromatin segments less than the number of chromosomes characteristic of the succeeding metaphase.

In the meantime, even before the reconstruction of the daughter nuclei in the last spermatogonial telophase, the cells have entered upon that period of remarkable growth characteristic of the spermatocytes of chilopods. This growth is so marked that at the time of the appearance of the nuclear membrane (Figures 3, 4) each of the daughter cells has attained a size about equal to that of the parent cell. In succeeding stages this increase in size continues (Figures 3–8), until finally in the vesicle stage (Figure 10) the diameter of the spermatocytes is more than ten times that of cells in the spermatogonial telophase. Thus the ultimate size of the spermatocyte in the vesicle stage is even greater than in Scolopendra.

At the time of the reconstruction of the nuclear membrane, as has already been mentioned, chromatin segments of the reduced number become scattered throughout the entire nuclear cavity (Figure 3). As the cell continues to grow these chromatin threads become more diffuse and the granules composing them become finer, and are now in a condition apparently similar in all respects to the segmented spireme stage of the spermatocytes of other animals. Now, however, a rearrangement of the chromatin begins to take place, which seems to be characteristic of chilopod spermatocytes and is seldom met with in the male cells of other animals. These changes have been studied in detail in Scolopendra (Blackman, :03, :05, :05^{a}) and in Scutigera (Medes, :05), and while they are essentially similar in these two genera, they still present several interesting minor differences.

In Scolopendra heros (Blackman, :03, :05) their changes are as follows: "The chromatin segments begin slowly to break down, and their substance becomes aggregated about the accessory chromosome, thus apparently increasing the size of this body enormously. This process continues until finally all of the chromatin of the cell is aggregated in one large intensely staining body." (Blackman, :05, p. 14.) This body I have called the karyosphere. It is not a simple homogeneous body of chromatin, but a very complex mass of chromatin fibres closely enveloping a solid chromatin body, the accessory chromosome. It is made up of chromatin, linin, and karyolymph, but contains no nucleolar material.

In Scolopendra subspinipes (Blackman, :05^a) the conditions are slightly different, owing to the presence of a true nucleolus. Here the karyosphere is formed by the massing together of all of the chromatin of the cell, but it also contains a nucleolus in addition to the material derived from the chromosomes. The chromosomic material is deposited in a dense granular mass over the outside of the nucleolus, forming a mantle around it.

In Scutigera forceps (Medes, :05) the origin of the karyosphere is quite similar to that in Scolopendra heros. The material composing it in these early stages is derived entirely from the chromosomes. Later, however, during the growth period, the karyosphere acquires in addition a large quantity of nucleolar material, as is shown both by its staining reaction in the vesicle stage and by the nucleolar residue remaining after the origin of the chromosomes in the prophase following. Thus, while the component materials of the karyosphere in Scutigera are identical with those of the same body in Scolopendra subspinipes, there is in the former no such definite localization of chromatic and nucleolar material as is found in the latter.

In the three species of Lithobius which I have now studied, two conditions exist as to the origin of the karyosphere. In Lithobius mordax the origin of the karyosphere is more like that in Scolopendra heros and Scutigera forceps, while in Lithobius multidentatus and Lithobius sp. the stages observed resemble more closely those found in Scolopendra subspinipes.

Stages in the formation of the karyosphere in Lithobius mordax are shown in Figures 3, 5, 6, 7, and 8. In Figure 3 the outlines of the accessory chromosome can still be distinguished. Closely apposed to one side of this element are several masses, which are more granular. These represent chromatin segments which have become shortened and thickened by a rearrangement of their granules, and have taken up a position upon one side of the accessory chromosome. Other chromosomes, still in the form of granular segments, are in contact with the forming karyosphere and very plainly are about to undergo a similar process. This disposition of the chromosomes around the accessory chromosome continues (Figure 5) until all of them are aggregated in one irregular densely staining mass, the karyosphere (Figures 6, 7).

In Scolopendra heros it was never possible to establish conclusively that the chromatin enters the karyosphere as definite individual chromosomes. That this is the case was, however, always believed by the author, and indeed there was considerable evidence supporting this view. In Scolopendra subspinipes more convincing evidence was found, as the nucleolar material there present serves as a background against which the chromosomes can be seen in favorable cases. However, some doubt might still remain.

The stages in the formation of the karyosphere in Lithobius mordax furnish better evidence of the individuality of the chromosomes during the early spermatocytic stages than those of any other myriapod yet studied. It can be very plainly seen that *the chromosomes enter into the formation of the karyosphere as distinct elements without losing their individuality.* Evidences of this fact are found at all stages in the formation of the karyosphere in the irregular lobulated structure of this body (Figures 5–8). Each one of these lobules undoubtedly represents a chromatin segment which has become shortened and thickened into an irregularly rounded body. In Figure 5 several of these chromosomes still remain detached from the rest and their identity is easily recognized. In Figure 6 the individuality of many of the elements may still be readily seen, while in Figure 7 the grouping of the chromosomes is but little closer.

Shortly after the stage shown in Figure 7, the karyosphere begins to undergo a change by which the dense mass of chromosomes is converted into the completely formed karyosphere of the vesicle stage. This change consists in the acquisition of a large amount of nucleolar material. This results in three changes in the appearance of the karyosphere. The first two of these are changes in size and shape, by which the irregular lobulated karyosphere of the young spermatocytes is converted into the larger spherical body characteristic of the vesicle stage. The presence of nucleolar material in the karyosphere also brings about a change in its staining reactions.

In Figure 8 is seen an early stage in this metamorphosis. By comparing the karyosphere in this cell with that shown in Figure 7, the changes mentioned above are immediately apparent. The karyosphere has undergone a considerable increase in size and a portion of the surface has assumed a regular rounded outline. The portion of the karyosphere possessing the regular outline has also changed in its reaction to the stains, showing that it is in this part that the nucleolar substance lies. Here certain rounded areas, which represent the chromosomes, still retain the haematoxylin strongly, while surrounding these chromosomes are irregular areas which show little or no affinity for the chromatin stains. Thus the rounding off of the karyosphere is due to the filling of the interstices between the chromosomes with nucleolar material, which thus acts as the matrix in which the chromatin is embedded. The acquisition of achromatic material continues during succeeding stages until, in the vesicle stage, the fully formed karyosphere is considerably larger, possesses a clearly cut outline, and is spherical in shape.

The origin of the karyosphere in Lithobius multidentatus and Lithobius sp.? differs from that in Lithobius mordax in several respects, and at this stage the cells resemble those of Scolopendra subspinipes more than they do those of Scolopendra heros. This is due to the facts that the young spermatocytes of these two species of Lithobius contain one or more true nucleoli and that this nucleolar material also enters into the formation of the karyosphere. In Figure 4 is represented a young spermatocyte of Lithobius sp.? showing an early stage in the formation of the karyosphere. The spermatocytes of this species are characterized by the presence of two or more nucleoli during the growth period. Figure 4 shows a cell possessing two nucleoli. Chromatin in the form of diffuse segments is already being deposited upon the surface of one of these, and the accessory chromosome may be seen embedded in one side of it. The other nucleolus (Figure 4) is still free of chromatin, but would later be involved in these changes also. Each nucleolus usually forms the basis for a separate karyosphere, as may be seen by referring to Figures 14, 16, 17. In Figure 15 one of the nucleoli contains no chromatin deposits whatever. This, however, is exceptional.

In Lithobius multidentatus the origin of the karyosphere is similar to that just described for Lithobius sp?, except that here only one nucleolus occurs, and only one karyosphere is formed (Figures 11–13).

After all of the chromosomes of the cell have become massed together to form the karyosphere, the remaining portion of the nucleus no longer stains deeply with chromatin stains (Figures 5, 6) and is no more dense in its structure than the cytoplasm. Soon irregular amorphous deposits appear in the nucleus, and these form a mantle surrounding the karyosphere. This mantle, however, does not envelope the karyosphere closely, but is separated from it by an area of transparent substance so that this body seems to lie in a vacuole of hyaloplasm (Figures 5, 6, and 7). The remaining portion of the nucleus is occupied by an irregular reticulum of linin fibres.

As the cell continues to grow this amorphous deposit increases in amount (Figures 8, 9, 10), until finally, in the vesicle stage, it forms quite a conspicuous portion of the nucleus (Figures 9, 10). Just what the significance of this material may be I am at a loss to say. From its straining reactions, however, it is seen that it is chemically similar to the nucleolar substance. In Lithobias mordax it is much more abundant than in either of the other species studied, while in Lithobius sp. ? (Figures 14, 17) very little if any occurs. Thus it varies inversely with the amount of nucleolar material contained in definite nucleoli. In Lithobius multidentatus less is present than in L. mordax, but in the former species (Figures 11, 13) it occurs in much more definite bodies, and these often approach nucleoli in form and structure. So the conclusion would seem justified that these deposits represent nucleolar material which has never become arranged in the form of distinct nucleoli.

We will now return to the early spermatocyte and consider thè evolution of the extra-nuclear structures. First, as regards the centrosome. In Scolopendra heros (Blackman, :05) I was so fortunate as to be able to find the centrosome during all the stages from the spermatogonium to the mature spermatozoön. Here it was readily found and recognized, owing to the fact that during the growth period it is enclosed in a specialized portion of the archoplasm. In Lithobius, however, such aggregations of archoplasm do not occur, and the centrosome has not been observed during the growth period. In Figure 7 two small, densely stained bodies enclosed in a denser portion of the cytoplasm are shown. It is, however, impossible to state with any certainty that these are centrosomes, owing to the fact that such structures have not been observed at other stages of the growth period. However, it does not necessarily follow that no centrosome exists during the growth period, as no determined effort has been made to find it and study it, as was done in Scolopendra.

The structure of the cytoplasm in Lithobius has been studied by P. et M. Bouin ('99), and by Meves und von Korff (:01). The brothers Bouin report the presence within the cytoplasm of Lithobius forficatus of certain irregularly formed bodies, which they have designated "formations ergastoplasmiques." These are believed to arise by the disintegration of the astral rays. Just before the prophase these deposits undergo what is described as a gelatinous metamorphosis and are not seen later than the early prophase. Meves und von Korff (:01), working on the same species, find these bodies in all phases of the first spermatocyte mitosis, although in later stages they are reduced to smaller granules. In Scutigera (Medes, :05) structures which are probably homologous are formed both in the nucleus and in the cytoplasm. These bodies, which are classed as metaplasm, stain densely and vary widely in number in different cells. As the prophase approaches, they begin to disintegrate, and soon disappear entirely.

In Scolopendra (Blackman, :05) there are two sorts of formations occurring in the cytoplasm. The first of these is the archoplasm, which is similar in structure to the cytoplasm and appears as a thickened and condensed part of it. The second consists of rather small, dark staining granules, which in appearance and behavior are similar to those in Scutigera. These undoubtedly represent metaplasm — either ingested food particles, or by-products of the cell activity.

In well-preserved cells of the three species of Lithobius studied I have been able to find no structures corresponding to the "formations ergastroplasmiques" of P. et M. Bouin, although in sections of poorly fixed material such deposits are often seen. The cytoplasm in Lithobius is very fine meshed and seems to be very difficult to fix properly. When wrongly treated, the fine reticulum becomes distorted and irregularly massed together in such a manner as to give the appearance of definite structures, and these I believe have been incorrectly regarded as normal structures. However, a few small, distinct *granules* do seem to be present at all stages of the first spermatocyte, and these I consider to be metaplasm, i. e., food material or by-products of metabolism.

In Lithobius no such aggregations of archoplasm exist as are characteristic of the growth period and vesicle stage of Scolopendra. On the contrary, all of the cytoplasm of the cell seems to be of about the same consistency. Indeed, both in structure and staining reactions the cytoplasm in the vesicle stage is quite similar to that in the prophase of the first spermatocyte of Scolopendra, after the archoplasm has been dissolved in the hyaloplasm and dispersed throughout the entire cell. This similarity and the fact that there are no special aggregations of archoplasm have led me to conclude that during the vesicle stage in Lithobius the archoplasm is dispersed throughout the cell. This causes the cytoplasm at this stage and during the early phases of mitosis to stain more strongly than at other times.

At the completion of the growth period the spermatocyte of Lithobius mordax in the vesicle stage presents the appearance shown in Figure 10. The size of the cells is remarkable, as they often reach an average diameter of more than 100 micra, thus being even larger than the spermatocytes of Scolopendra and Scutigera. In the various species of Scolopendra (Blackman, :01, :05, :05^a; Bouin, :03, :03^a) the spermatocytes in the vesicle stage are of two distinct types as to size. In Lithobius, however, while there is considerable variation in the sizes of the cells during the vesicle stage, no such great differences exist, and the cells cannot be divided into two types on this basis.

The cells in the vesicle stage of the three species of Lithobius are quite similar to one another as regards the extra-nuclear portion, but differ considerably in the structure of the nucleus, so much so that the species may be readily identified by this alone. The differences existing between Lithobius mordax and L. multidentatus are less apparent than those between either of these and the Bermuda species, yet very little study is necessary for identification. The greatest of these specific differences are seen in the structure of the karyosphere, but the condition of the achromatic structures also varies in the three species.

What may be taken as the typical appearance of the nucleus in Lithobius mordax is shown in Figure 10. The karyosphere is stained an intense black with haematoxylin and green with the Ehrlich-Biondi mixture, showing that it is rich in chromatin. However, in many sections in which the decolorizing has been carried further, the entire karyosphere does not take the chromatin stain, thus showing that this body is not made up entirely of chromatin, as is that of Scolopendra heros, but contains nucleolar material also, as do the similar structures in Scolopendra subspinipes and Scutigera forceps. A karyosphere of this sort is shown in Figure 9. Here the chromatin is arranged in the form of a network of anastomosing strands which are embedded in the nucleolar substances. No portion of the nucleus except the karyosphere contains any chromatic material. The conspicuous deposits which form an irregular mantle around the karyosphere are very evidently achromatic material, as is shown by their staining reactions.

In Lithobius multidentatus the karyosphere is much like that just described. The chief difference lies in the fact that here the amount of chromatin to each cell is considerably less. Thus the karyosphere is not usually stained so black and the nucleolar portion is more evident (Figures 11, 12, 13). It is also true that the chromatin is usually found only on the periphery of the karyosphere outside the nucleolus, resembling in this respect Scolopendra subspinipes. The deposits of achromatic substance in the nucleus are much less abundant and are in more definite bodies, thus allowing more of the linin network to be seen.

The nucleus in Lithobius sp. ? differs from that of either of the two species described in several particulars. There are no indefinite masses of achromatic material, this all being incorporated in the nucleoli, of which there are several, the amount of nucleolar material being greater. Usually each nucleolus contains one or more chromosomes and thus constitutes a karyosphere (Figures 14–17). The number of karyospheres in a nucleus varies from one (Figure 15) to four (Figure 18) or even six, the most common number being two (Figure 16), while three are often seen (Figures 14, 17). When the number of karyospheres is greater, the relative amount of chromatin in each is smaller and the chromatin occurs in more definite masses. Often it is arranged in the form of a single thread embedded in the nucleolar material (Figure 14), while in other cases it occurs in several irregular masses (Figures 14, 15, 17). It is usually enveloped in the nucleolus and not deposited upon the periphery, as in Lithobius multidentatus.

The origin and behavior of the chromosomes during the prophase of the first spermatocyte of myriapods has been described differently by different workers. The first account is that by Carnoy ('85), which deals with the spermatocyte mitoses of Lithobius forficatus, Scutigera arachnoides, Geophilus, and Scolopendra dalmatica. In Lithobius, Scutigera, and Geophilus the nucleole-noyau (karyosphere) gives rise to the chromatin thread, from which the chromosomes are derived. The process of tetrad formation was not studied at all. In Scolopendra dalmatica the nucleolus is said to take no part whatever in the origin of the chromosomes.

Later investigators upon European myriapods have arrived at results quite different from those of Carnoy. Meves und von Korff (:01) confined their observations almost entirely to the peculiar modification in the achromatic division figure of the first spermatocyte of Lithobius forficatus. The chromosomes were but little studied, and those figured are already in the form of distinct elements. The description, however, gives the impression that they arise from the network of the nucleus.

In several short papers from the University of Nancy, P. Bouin, M. Bouin, and R. Collin have dealt briefly with the chromosomes, although most of their work has been upon achromatic structures. In Geophilus linearis P. Bouin et R. Collin (:01, page 101) find no connection between the large "nucleolus" and the origin of the chromosomes, but on the contrary state that these elements arise from a chromatic reticulum: "Le réticulum chromatique est constitué par de très fins microsomes distribués sur les mailles du réseau de linine; au niveau des points d'entrecroisement de ce réseau, ils sont rassemblés en amas plus ou moins volumineux. Ces microsomes chromatiques se réunissent bientôt en petites masses qui se condensent rapidement en sphérules homogènes ; celles ci paraissent subir tout de suite une segmentation transversale. Peu de temps après le début de ces processus on peut voir, disséminés dans l'aire nucléaire, et aussi bien contre la face interne de la membrane du noyau que sur les travées du réseau lininien, des chromosomes segmentés transversalement et qui figurent, comme l'un de nous l'a déjà signalé à propos du Lithobius forficatus, des sortes de diplosomes chromatiques minuscules. Ces diplosomes, chez Geophilus linearis, sont au nombre de huit. Ils nous a été impossible, à cause sans doute de l'extrême petitesse de ces formations, de nous rendre compte si les indices de la deuxième division de maturation apparaissaient sur ces chromosomes dès ce stade de la caryocinèse." The authors conclude that each of the succeeding mitoses results in a transverse division of the chromosomes.

The criticism by Grégoire (:05) of these results of Bouin et Collin seem to me to be just. He says (p. 284) : "Cette interprétation appelle plusieurs remarques. D'abord, si la description des auteurs est exacte, il faut reconnaître que cet objet est détestable pour l'étude du subjet actuel et qu'on n'en peut tirer de conclusion d'aucune sorte. En effet, il semble bien impossible de savoir si la division en deux d'une 'sphérule' constitue une division transversale à mettre sur le pied de ce qu'on appelle ailleurs de ce même nom ; de plus, à la seconde cinèse, comment fixer la valeur de la bipartition d'une 'granulation minuscule' ? L'objet, tel qu'il est décrit, serait donc à condamner au point de vue actuel."

In a later paper P. Bouin et M. Bouin (:02) have published the results of their studies on the chromatin reduction in Lithobius forficatus. Here the chromosomes are larger than in Geophilus, although still somewhat smaller than those described in this paper. The authors believe that in Lithobius also the chromatic elements have no connection with the large "nucleolus." But in the figures accompanying this and other papers on the same species, it is seen that at the beginning of the prophase the nucleolus is large and stains like chromatin, while later, after the chromosomes are formed, it is much smaller and more lightly stained. However, the authors state that the chromosomes arise from the nuclear reticulum. The chromatin granules, while still a part of this network, undergo cleavage, so that each thread of the reticulum becomes double. Later the chromatin granules collect and fuse to form bipartite chromosomes or "diplosomes." No true tetrads were observed, but the authors conclude that reduction is accomplished by a longitudinal division followed by a transverse division.

In the American myriapods the origin and behavior of the chromosomes of the first spermatocytes have been studied in three species: in Scolopendra heros (Blackman, :01, :03, :05), in Scolopendra subspinipes (Blackman, :05^a), and in Scutigera forceps (Medes, :05). In these species the essential phenomena are similar, although the details of the processes vary considerably. In all three forms the chromosomes arise from chromatin stored in the karyosphere. The chromosomes appear first as segments equal in number to the elements later taking part in mitosis. These granular segments undergo first a longitudinal and later a transverse cleavage, and soon take on the well-known cruciform shape characteristic of the heterotypical chromosomes of invertebrates. During the late prophase the chromatin granules fuse and the tetrad becomes a homogeneous four-lobed chromosome.

The formation of the tetrads in Scutigera varies in one interesting particular from the typical process as observed in Scolopendra, as has been shown by Medes (:05, p. 163): "Immediately after leaving the karyosphere the chromosomes shorten into dense granular cords. These now undergo a longitudinal cleavage and the double thread of chromatin breaks up into a number of short portions of irregular size." These portions are spherical in shape and of homogeneous consistency; they appear to be lobules of chromatin in a liquid condition.

In describing the origin and behavior of the chromosomes of the first spermatocyte in the forms used in the present paper, the observations upon Lithobius sp.? will be given first, as here the phenomena are more like those observed in other animals. Indeed, as regards the changes in the chromosomes themselves, the nuclear processes are nearly identical with those in Scolopendra. The first change in the nucleus during the prophase has to do with the appearance of the chromosomes, which, as we have already seen, unite with the nucleoli during the early part of the growth period to form several karyospheres. During the growth period and vesicle stage this chromatin may be seen in the karyospheres as dense masses or threads embedded in the nucleolar material. The first change in the nucleus is in this chromatin. The dense masses become more granular and more diffuse and move to the surface, thus coming to lie outside the nucleolar portion. Strands of the chromatin leave the karyosphere and lie free in the nucleus. This process continues until all of the chromatin has left the karyospheres. When this is accomplished, the number of chromatic segments in the nucleus is the same as the number of chromosomes participating in the succeeding division. Figure 18 (Plate 1) represents an advanced stage in the disintegration of the karyospheres. Many of the chromosomes are already free, while those which still remain in the karyosphere are spread out as diffuse flocculent deposits upon the surface of the nucleolar portions.

In later stages (Figures 19–21), when all of the chromosomes are free in the nucleus, the nucleoli, much reduced in size, may still be seen. These nucleoli, although at first spherical (Figure 21), soon become irregular in outline and rapidly disintegrate (Figures 19^c, 20). At least a portion thus set free in the nucleus is used in the evolution of the chromosomes.

The chromatin segments of the reduced number as they arise from the karyosphere are diffuse granular threads (Figure 18). These soon elongate, and the granules composing them become coarser. The segments assume a variety of shapes, but most often they are roughly U-shaped or V-shaped, just as they were in the early spermatocytes before they entered the karyosphere. At about their middle point, — i. e., at the angle of the V, or at the loop of the U, — there is very often a small gap in the chromatin thread (Figure 18), as has been observed by several investigators on other material (Montgomery, :00, :05 ; Sutton, :02 ; Blackman, :03, :05, 05^a ; Foot and Strobell, :05). This undoubtedly represents the point at which the conjugating chromosomes united during synapsis.

Soon each segment undergoes a longitudinal splitting, resulting in two more slender segments (Figures 19^a–21). The halves thus resulting typically lie parallel to each other, but very often they are twisted about each other, as is shown by several chromosomes in Figures 19^a and 20. Less often the ends of the halves may be separated and drawn in opposite directions, as is the case with several chromosomes in Figures 19^a and 19^c. Typically, however, the two threads lie near each other and are approximately parallel.

The next change in this double segment consists in the cleavage of each of the halves at about their middle point, resulting in a four-parted chromosome or tetrad. This is a transverse division of the chromosome and occurs at the point where in preceding stages an interruption in the chromatin was observed. Thus, when this division is completed, it results in the separation of entire spermatogonial chromosomes.

As soon as the transverse cleavage is established the chromatids revolve upon each other in one of several ways, producing tetrads varying in shape, but all referable to one type. The more common method is as follows : At the point of transverse cleavage the threads show a tendency to bend at a more or less acute angle, and in each half-segment the adjacent ends produced by the cross division become drawn out in the same direction, but perpendicular to the axis of the original thread, while the corresponding portion of the other half is drawn out in the same plane, but in an opposite direction. This results in the typical cross-shaped figures shown by several tetrads in Figures 19^b and 20. The four arms of the cross are approximately equal in length, and each arm is split longitudinally. Thus the chromosome is formed of four chromatids, each of which consists of a continuous chromatin thread extending the length of the two adjacent arms and forming one half of each (Figures 19^b, 20). Another common shape assumed by the tetrad is illustrated by the double-V figures (Figure 20), similar to those observed in other animals by Paulmier ('98), McClung (:00, :02), Sutton (:02), Blackman (:01, :03, :05, :05^a), Foot and Strobell (:05), and others. These are obtained by a longitudinal and transverse division of the V-shaped segments, no rotation of the chromatids occurring. A third form of the tetrad is shown by chromosomes in Figure 22. Here the straight segment undergoes the two cleavages, as in the more common type. It is not converted into the typical cross-shaped figure, however, but remains as a straight band of chromatin consisting of four parts — the chromatids.

In later stages of the prophase the changes in the tetrads consist principally in a contraction of the arms and a condensation of the chromatin. Thus, in a fairly late prophase (Figure 22) the more common form of the chromosomes is still that of a cross, but the arms of the cross are much shorter and thicker, and in the more advanced tetrads the condensation of the chromatin granules has proceeded so far as to mask the planes of cleavage, these being seen only in the most favorable cases. In still later stages the chromatin becomes more condensed, and the tetrad goes to the equatorial plate as an apparently homogeneous body typically of a four-lobed shape.

Some of the chromosomes in the process of condensation pass through stages similar to those described by Medes (:05) in Scutigera. The chromatin, instead of massing together into one body, becomes condensed into a number of homogeneous globules, which lie embedded in a more lightly staining substance (Figure 22). These globules later fuse in such a manner as to form a metaphase chromosome of typical appearance. This process will be followed more in detail in the other species of Lithobius, where it is the common method.

The nuclear changes during the prophase in Lithobius mordax and Lithobius multidentatus will be treated at one time, as they are essentially similar in the two forms. In both of these forms all of the chromatin of the nucleus is massed in a single karyosphere, which also contains a considerable portion of nucleolar material. In addition to this there are plentiful deposits of achromatic material in the nucleus, it being more abundant in Lithobius mordax than in the eastern species. This material, although purely achromatic in nature, plays a part in the evolution of the chromosomes.

Just as in Lithobius sp. ?, the first nuclear change in the prophase of the first spermatocyte concerns the chromatin in the karyosphere. This leaves the dense masses and collects near the periphery either in the form of coarse granular flakes or loose aggregations of small globules. At the same time the achromatic deposits in the nucleus break up into a number of diffuse, lightly staining masses (Figure 13), which come into relation with the chromosomes as they arise from the karyosphere and become a part of them.

The chromatin arises from the karyosphere (Figure 23) in the form of small globules, which, as they leave the karyosphere, become embedded in the diffuse masses of the achromatic substance. These masses of achromatin lengthen out into short segments, and in each of these the chromatin becomes arranged in the form of distinct darkly stained globules (Figure 23). Thus each of these composite masses at this time consists of a diffuse, lightly stained band of achromatic material, in which is embedded a single row of intensely black globules of chromatin. These globules at this stage are always of about the same size, and are always spherical, presenting the appearance of droplets of liquid chromatin. It is not always easy to observe the typical arrangement of the chromatin globules, as the chromosome is often so bent, or in such a manner distorted, as to obscure their linear arrangement.

The changes immediately following the origin of the chromosomes are similar in results to those in other animals. Each globule is divided into two equal parts, so that the chromosome, instead of being composed of a single row of chromatin particles, now consists of two such rows (Figure 23), each of which contains the same number of globules. This undoubtedly represents a longitudinal division of the chromosome, as the linear arrangement of the globules doubtless has the same significance as the similar arrangement of the granules in the ordinary chromatin segment of the prophase. Following the longitudinal splitting, the transverse cleavage is accomplished in the same manner as in Lithobius sp. ? by a division of each row of globules at its middle. The four chromatids thus produced may rotate upon each other in such a way as to result in the typical cruciform tetrad (Figure 23), or may remain a double row of granules with a gap between the two pairs nearest the middle wider than that between any other two pairs. In Figure 23 two tetrads showing the typical cross-shaped form are shown; these are redrawn at the side of the figure with the achromatic portions omitted and the globules comprising each chromatid connected by lines, in order to show diagrammatically the author's interpretation of their structure.

Owing to the distortions of the arms of the tetrad, it is often difficult to correlate the chromosomes at this stage with the type forms described. In later stages this difficulty is rendered still greater by the changes which next take place. These have to do with the condensation of the chromatin by which the tetrads of this stage are converted into the homogeneous chromosomes of the metaphase. The condensation is accomplished by the fusing together of the chromatin globules composing each chromatid of the tetrad. It eventually results in the production of a tetrad made up of four large, deeply stained chromatin globules, each one of which represents a chromatid (Figure 25).

Tetrads when they have reached this stage are very readily understood and correlated with those of an earlier period. The intervening stages (Figures 24, 25), however, proved rather puzzling. These are much more numerous, and were observed before either the foregoing or succeeding ones were found. After all stages were studied, however, the interpretation was simple. All of the chromatin globules belonging to a chromatid do not fuse at once, but this is a process involving considerable time. Thus the chromosomes may contain a variable number of globules, and these often are of very different sizes (Plate 1, Figures 24, 25 ; Plate 2, Figure 26). In other cases chromosomes were found containing from six to ten spherules of approximately equal size (Figures 24, 25, 27). The latter fact at first inclined me to the belief that the chromosomes here were multiple chromosomes similar to those found by Sinéty (:01) and McClung (:05) in insects, where some chromosomes possess as many as ten chromatids. However, a study of the chromosomes in the late prophase and in the metaphase (Plate 2, Figures 28, 29, 30) rendered this plausible view untenable. The fusing of the chromatic globules continues until all belonging to one chromatid have united to form one large spherule of apparently pure chromatin.

The structure of the chromosome when it has reached this stage is shown by several examples in Figures 25 and 26. The four chromatids, of about equal size and arranged symmetrically, are enclosed in an irregular homogeneous or granular mass of achromatic material. In the later prophase (Figures 26, 27) this achromatic mantle contracts and becomes more dense, serving to bind the four parts of the chromosome together. Thus the chromosomes at the time of the breaking down of the nuclear membrane are four-lobed structures, which in Lithobius mordax are apparently homogeneous in consistency.

In Lithobius multidentatus the formation of the tetrad is similar to that in the western species. Apparently the only difference in the chromosomes of the two species is in the smaller size of those in L. multidentatus (compare Figures 26 and 27 with Figure 28) and in the relatively larger amount of achromatic material contained in the fully formed chromosomes. In Figures 26 and 27 are seen various late stages in the evolution of the tetrads. The younger stages here shown are practically identical with those of the other species. The later stages, however, are here much clearer. The larger quantity of achromatic material causes the component parts to be more loosely bound together, and the individual chromatids may be readily distinguished. It is possible even to recognize the planes of the cleavage, although it cannot be said with certainty which is longitudinal and which is transverse.

When all of the chromosomes have left the karyosphere, the body remaining is purely nucleolar in nature and stains lightly (Plate 1, Figures 24, 25). It is considerably smaller than the karyosphere, and in succeeding stages of the prophase gradually disintegrates. Usually it breaks up into a number of irregular granular bodies, which may persist even to the stage of the metaphase or anaphase (Figures 30, 32). In such cells these particles are usually grouped irregularly in the cytoplasm near the poles of the nuclear spindle, as has been observed in both Lithobius by P. Bouin (:01), by Meves und von Korff (:01), and in Scutigera by Medes (:05). In other cells, however, the nucleolus seems to disappear entirely, there being no residue at the time of the formation of the spindle (Figure 29).

Often the nucleus, instead of breaking up into several granular masses, becomes dissolved in the nuclear sap while retaining its spherical shape. In such cases its circumference often remains about the same, and sometimes even increases. An example of this is shown in Plate 1, Figure 23, the increase in circumference being due to the presence of a large vacuole, which represents nucleolar material converted into a liquid. The contents of the vacuole remain entirely unstained. In later stages more and more of the nucleolus undergoes this change, until eventually none remains.

The changes in the achromatic structures in chilopods, and the peculiarly modified spindle occurring in these forms, have been the subject of several papers. Meves und von Korff (:01) confined their observations to the first spermatocyte division. The centrosomes during the early prophase are not upon the nuclear membrane, but lie at a considerable distance from it. In later stages of the prophase they diverge and pass through the cytoplasm to the cell membrane, where they take up a position at opposite sides of the nucleus. Later, the nuclear spindle arises, but the mantle fibres have no connection with the centrosomes, each fibre ending free in the ctyoplasm. The astral fibres radiating from the centrosomes have no connection with the spindle.

The observations of P. Bouin (:00, :01) upon the same species are practically identical with the foregoing, and those of Bouin et Collin (:01) extend these observations to Geophilus linearis. These authors (p. 106) reach the following conclusions regarding the modified spindle: "De cette étude sur le fuseau chez le Geophilus linearis nous nous croyons autorisés à conclure qu'il existe également chez ce Myriapoda une indépendence complète entre le fuseau d'une part, les sphères et les corpuscles polaires, d'autre part, indépendence evidente au stade de la métacinèse, plus difficilement observable, mais très vraisemblable cependant dès prophases de la mitose."

In Scutigera forceps (Medes, :05) much the same condition exists in the fully formed spindle, although earlier stages in its formation present some important differences, and at this time more closely resemble corresponding stages in the small spermatocyte of Scolopendra (Blackman, :01, :05). The centrosomes at first lie at the poles of the spindle. Later, however, they leave this position and migrate to the cell membrane, retaining no apparent connection with the nuclear spindle. During the metaphase the author (Medes, p. 168) states: "The mutual independence of the spindle-fibres and the astral rays in Scutigera is the more clearly shown by the great dissimilarity in their structure and general appearance; for while the latter are very fine and delicate, . . . the former are heavy, stain an intense black, and present the appearance of wires, the ends of which may be distinctly seen lying free in the cytoplasm."

In the present study of the achromatic structures the cells of Lithobius mordax have been used almost entirely, although observations showing that the changes are common to the genus have been made on the other two species. It will be seen that in general my observations on the achromatic structures are largely confirmatory of those on the European species of Lithobius made by Bouin (:00, :01) and by Meves und von Korff (:01).

In the prophase of Lithobius mordax the centrosomes were first seen in cells in which the nucleus is about in the stage represented in Plate 1, Figure 23. At this stage there are two, one lying at each side of the nucleus and about midway between this structure and the cell membrane. Each centrosome has already begun to divide to produce the centrosomes of the second spermatocyte mitosis, and is now a small, darkly stained, dumb-bell shaped body. It lies in a small, clear area of the cytoplasm, and is surrounded by astral radiations which, though very fine and delicate, are still distinct from the cytoplasmic reticulum.

In later stages the centrosomes move through the cytoplasm toward the cell membrane, and finally take up their position on the inner face of this structure. In this migration they do not move in opposite directions, but proceed toward the side of the cell nearest to a line connecting the two centrosomes. Thus when they reach the cell membrane they usually both lie upon one side of the cell, which as yet still preserves its rectangular outline (Figures 24, 25). During this migration the nucleus also undergoes a movement in a similar direction, seemingly striving to retain its position in a line between the two centrosomes. Thus at a time when the centrosomes have reached the cell membrane, the nucleus lies very near to the same side of the cell, as is shown in Figure 25. When the centrosomes come in contact with the membrane, they immediately begin to move apart along its inner face until they have reached opposite poles of the cell, the nucleus meantime changing its position so as to lie between the two (Figure 24).

Meanwhile the centrosomes have changed considerably in appearance. By the time they have reached the cell membrane each is enclosed in quite a distinct centrosphere. This is homogeneous or finely granular, and stains slightly darker than the cytoplasm (Figures 24, 25). The astral rays have increased both in size and number, and now penetrate to nearly all regions of the cytoplasm. Those from the two poles may be distinctly seen to cross one another near the centre of the cell (Figures 24, 25), although this crossing is not so apparent as it is later (Figure 28). These fibres are entirely distinct from the cellular network, as the cytoplasmic reticulum is still evident except in the regions immediately surrounding the poles. In these regions, however, the network seems to have entirely broken down, leaving only the hyaloplasm and the penetrating astral rays. Thus each centrosphere is surrounded by a transparent area of considerable width (Figures 24, 25), which serves as an excellent background for the centrosome and centrosphere. Appearances similar to this have been observed in other myriapods by Meves und von Korff (:01), P. Bouin (:00, :01), and Medes (:05).

During the time of the divergence of the centrosomes upon the cell membrane the cell has altered considerably in shape. In the vesicle stage and early prophase the cells are typically rectangular in outline. Now, however, they undergo a change by which their form becomes approximately spherical. This I believe to be directly due to the appearance and development of the archoplasm (Blackman, :05), for the rounding off of the cell is only perfected when the astral systems have reached the height of their development (Plate 2, Figures 28–30).

The achromatic changes thus far described have been entirely independent of the nucleus, but during this same period the nucleus is also active. Aside from the evolution of the chromosomes and the disintegration of the nucleolus, which have already been described, the linin reticulum has also changed. Before the origin of the tetrads, a considerable portion of the nuclear area is occupied by the diffuse masses of achromatic material, which is so abundant as to obscure the greater part of the nuclear framework (Figures, 9, 10). After the chromosomes have arisen from the karyosphere, however, this diffuse material is collected into smaller and denser masses, which closely surround the chromosomes. Thus the linin network is rendered visible and is seen to consist of a coarse, irregular reticulum (Figures 23–25). At first this is granular and stains very diffusely. As the tetrads condense to form the homogeneous chromosomes of the metaphase, the network becomes coarser and more irregular. At the same time the linin fibres begin to lose their granular appearance and to take on the form of more definite threads, which retain the stains much more strongly. Thus the nucleus in the late prophase presents the appearance shown in Figures 26 and 27 (Plate 2). The linin network is much more irregular than in preceding stages, and at many places is made up of distinct threads which have lost their granular structure. In later stages they become more and more numerous and definite, and the network becomes more and more broken up, although as yet the fibres have no definite arrangement with reference to the poles of the cells.

The breaking down of the nuclear membrane and the formation of the central spindle is a process involving considerable time, as is shown by the numerous cells found in these stages. The nuclear membrane disappears rather early, often before all of the chromosomes have attained their homogeneous structure. The distinction between nuclear and cytoplasmic material is not so early lost, however, and may indeed be seen until the following anaphase. In the late prophase the line of demarcation between nuclear material and cytoplasm becomes very irregular, and shortly before the completion of the spindle presents the appearance shown in Figure 28. The distinction between nuclear sap and cell sap is shown by the much more transparent appearance of the former. The linin at this time (Figure 28) is all in the form of definite threads, and these are being oriented so as to point toward the poles.

In the later prophase this orientation of the linin fibres continues until it eventually results in the formation of such a spindle as is represented in Figures 29, 30. The central spindle is derived from the nucleus, as is shown by numerous stages in its formation. The chromosomes lie near the centre and are arranged in nearly one plane, forming an equatorial plate. Extending from the chromosomes toward the poles are the linin fibres, which have now become mantle fibres. These at first (Figure 29) are comparatively short, but later they lengthen (Figure 30) and extend about one half of the distance from chromosome to centrosome. They are much thicker than the astral rays and stain much darker. The central spindle, or nuclear spindle, is entirely distinct from the astral systems and lies in a clear area devoid of reticulum, which represents the nuclear sap that has not yet become mixed with the cytoplasm. The entire spindle is barrel-shaped, the fibres converging slightly, but not coming to a point. At this time, and at all later stages of mitosis, the fibres if continued through the cytoplasm would converge at the centrosomes, thus showing that these small bodies, while not directly connected with the nuclear spindle, still are the directing forces which determine its orientation and toward which its fibres converge.

During the late prophase and metaphase the astral systems continue to develop, the rays becoming longer and more numerous. In the equatorial region they may often be seen to cross, although this crossing of the rays is not so pronounced as it is later during the anaphase (Figure 32), at which time the archoplasmic structures reach their highest development. In the metaphase (Figure 30) the centrosome has often already divided to form the centres of the second division, and this is always completed by the anaphase. The two centrosomes are surrounded by the centrosphere just as in the prophase. The lighter area of cytoplasm surrounding the centrosomes, however, is usually much reduced by the time the spindle is completed (Figure 29), and usually disappears entirely in the early anaphase. The cell membrane in the region of the centrosomes is always depressed during metakinesis and cytoplasmic cleavage (Figures 29–34). This depression first becomes apparent in the late prophase at the time the outline of the cell is becoming rounded. This phenomenon probably has the same significance as that ascribed to it in Scolopendra (Blackman, :05, p. 55).

With the formation of the nuclear spindle the chromosomes, which heretofore have been scattered throughout the nuclei, become lined up near the middle of the spindle to form a fairly definite equatorial plate (Figures 29, 30). While they do not all lie in exactly the same plane, they are still arranged much more regularly than in Scolopendra. We have seen that the characteristic form of the chromosomes in the late prophase is that of a four-lobed structure, each lobe representing a chromatid. The chromosomes in the equatorial plate are likewise typically of this form, yet there are individual variations both in the form of the tetrads and in the attachment of the mantle fibres which are interesting and instructive. A peculiarity seen in these chromosomes which I have not seen reported by any other observer is shown in Figures 29–31. The chromosomes here represented were studied in preparations in which the extraction of the haematoxylin had been carried farther than usual. This caused the greater part of the chromosome to stain not a dense black, but a dark gray. At the ends of each tetrad, at the point where the mantle fibres attach, there is a small, distinct body which stains much darker than the rest of the chromosome, and is of about the size of the centrosome (Figure 31). This spherule is embedded in the chromosome and is continuous with the mantle fibre and appears to be an enlargement or knob upon the end of this thread. Whether this body has any other significance than that of serving as an attachment to the chromosome I am unable to say, but it is a very distinct structure and is always found in the metaphase chromosome. The position of this body is very useful in determining the exact point of attachment of the mantle fibres and as an aid in determining whether the division of the chromosome is transverse or longitudinal. Usually the mantle fibres are attached at opposite ends of the four-lobed chromosome, and in such cases the fact that the division is longitudinal can be determined only by the shape assumed by the chromosome during the gliding apart of the two component dyads (McClung, :00; Blackman, :03, :05). Quite often, however, the mantle fibres attach to two of the adjacent lobules or chromatids of the tetrad (Figure 31). In such cases the chromosome lies with its longer axis parallel to the equatorial plate and division occurs by the separation of the chromosome along its longer axis. Such chromosomes are seen in all equatorial plates studied and are represented in Figures 29–31.

Thus the shape of the chromosomes at this time strongly indicates that the division of the first spermatocyte is a longitudinal one, but the best evidence of this is seen in the early prophase and during the anaphase of the first spermatocyte division. We have seen that in the prophase the first change in the chromatin segment consisted in the longitudinal cleavage. It is but natural, then, to believe that this longitudinal division is the one first completed in the two mitoses following. In the anaphase of the first spermatocyte, strong evidence as to the character of the chromosomic division just completed is furnished by the shape of the daughter chromosomes during their passage toward the poles. In Figure 32 is shown a mid-anaphase of the first spermatocyte. The chromosomes are already approaching their final position, but as yet are not massed together as they are at a slightly later stage (Figure 33). The chromosomes are of a distinctly dumb-bell shape, the constriction at the middle of each one representing the line of transverse cleavage at which point the chromatids separate during the following metaphase. During the succeeding stages (Figures 33, 34) and in the prophase of the following mitosis (Figure 35) the chromosomes retain this shape. In the metaphase of the second spermatocyte (Figure 36) the dumb-bell shaped elements are arranged with the constriction parallel to the equatorial plate and the separation of the component chromatids occurs at this place. This is the reduction division of the chromosomes, and by it the parts of the bivalent element are separated, doubtless at the same point at which they united during the telophase of the last spermatogonium.

In the meantime the nuclear spindle of the first spermatocyte remains entirely independent of the centrosomes and their system of astral rays. During the division and separation of the chromosomes the mantle fibres elongate considerably and their polar ends approach the centrosomes (Figure 32), but at no time do they abut upon it. Thus the chromosomes are evidently not separated by the contraction of the mantle fibres, but these seem merely to act as runways along which the daughter chromosomes move as they approach the poles. This, however, does not necessarily mean that the centrosomes do not have an important function in the separation of the chromosomes, for the influence of the chromosomes over the nuclear spindle is at all times apparent. The nuclear spindle is oriented parallel to a line connecting the two poles of the cell, and at all stages the mantle fibres converge toward the centrosomes. It seems probable that the separation of the daughter chromosomes is accomplished by an attractive force exerted upon them by the centrosomes rather than that they move apart by a force inherent in themselves. At any rate it cannot be disputed that the centrosomes determine the direction of this migration.

In a former paper (Blackman, :05) I have given at some length reasons for believing that the centrosomes and astral rays play an important part in the cytoplasmic cleavage. This work upon Lithobius strengthens the belief there expressed by showing that similar phenomena occur here also. The astral rays are not so conspicuous as in Scolopendra, but in all other respects they are essentially the same, and in Lithobius, just as in Scolopendra, I believe that the constriction of the cell is brought about by a force which is inherent in the centrosome and is exerted upon the cell membrane through the astral rays.

The further changes in the maturation divisions offer but few points of special interest, and will be treated very briefly here. After the separation of the chromosomes in the first spermatocyte division, the mantle fibres extend between the two masses of daughter chromosomes, presenting the peculiar appearance shown in Figure 33. The nuclear substance may still be distinguished from that of the ordinary cytoplasm by its more transparent appearance. With the constriction of the cell, however, the distinction between nuclear-sap and cell-sap is finally lost, although a disc of more transparent material still remains in the plane of constriction until cell division is nearly complete (Figure 34).

By the constriction of the cell, the interzonal filaments are grouped together in a sheaf-like bundle. This is much shorter and broader than in Scolopendra, and persists but a short time. At the plane of constriction each fibre is interrupted by a small enlargement. These bodies at first occur only in the superficial fibres, where, by their fusion, they form a darkly stained ring about the sheaf of spindle remnants (Figure 35). Later, however, as constriction proceeds still farther, the interzonal filaments entirely disappear, while the ring surrounding them at a former stage has been converted into a darkly stained plate. This is continuous with the constricted cell membrane, and closes the opening between the two daughter cells. In sections it appears as a black band, and extends through a considerable depth of focus.

The second spermatocyte mitosis follows the first very closely, there being no distinction between the telophase of the first and the prophase of the second division (Figure 35). The centrosomes do not leave their position upon the cell membrane, but in separating move along this structure until they arrive at opposite sides of the cell. The nuclear membrane then breaks down, and the spindle is formed. This spindle, just as in the first spermatocyte division, is truncate at the poles and remains entirely distinct from the astral systems.

The succeeding changes in the second mitosis are so similar to those in the first spermatocyte as to render separate description unnecessary. The dividing cells in the second spermatocyte may, however, always be readily distinguished from those of the first by several characteristics. The cells are much smaller, the spindle is more attenuated, and the chromosomes are of quite a different shape. The changes in the spermatid during its development into the spermatozoön will be the subject of a later paper.

SUMMARY.

Pseudo-reduction is accomplished by an end-to-end union in pairs of the chromosomes during the telophase of the last spermatogonial division. All of the chromosomes take part in this except the accessory chromosomes.

During the early part of the growth period *all of the chromosomes become massed together to form the karyosphere. The chromosomes enter this body as distinct elements, and the individual elements can be recognized for a considerable time.* The karyosphere also contains nucleolar material.

The karyosphere varies in structure with the species. In Lithobius mordax the amount of nucleolar material is less than in the other species studied. In Lithobius multidentatus the chromatin is peripheral in position, and surrounds the nucleolar material. In Lithobius sp. ? the amount of nucleolar substance is greater, and there are always two or more karyospheres. The chromatin in this species is usually central in position, and is surrounded on all sides by nucleolar material.

During the growth period *no special aggregations of archoplasm are present, but this substance is dispersed throughout the cytoplasm of the cell.*

In the three species of Lithobius studied *the chromosomes arise from the karyosphere* and develop into tetrads, but the manner of development of the tetrads varies with the species.

In Lithobius sp. ? the stages in the formation of the prophase chromosome are similar in all essential respects to those of the typical arthropod tetrad.

In *Lithobius mordax and Lithobius multidentatus the chromatin arises from the karyosphere in the form of globules which, as they arise, become arranged in a single row for each chromosome, and each chromosome is embedded in a separate mass of achromatic material.* In the formation of the tetrad *each globule divides into two equal halves, giving rise to two parallel rows of globules. This represents the longitudinal or equational division of the chromosomes. The transverse or reduction division is accomplished by a separation of the rows of globules at their middle point, the globules themselves remaining intact. In later stages the globules forming each chromatid fuse into one, thus giving rise to a tetrad composed of four spherules of chromatin.*

After the origin of the chromosomes, the nucleolar portion of the karyosphere remaining gradually breaks down. Portions of it may often be seen at the poles of the nucleolar spindle during the metaphase and anaphase of the following division.

In the early prophase the *centrosomes separate and move through the cytoplasm to the cell membrane.* Along the inner face of the membrane they migrate apart until they are upon opposite sides of the cell. During the migration the cell outline becomes rounded off, and by the time of the metaphase the cell is spherical in shape.

When the centrosomes are at opposite sides of the cell the nuclear membrane breaks down, and its component parts become rearranged to form a spindle. *The linin network is transformed directly into the mantle fibres.*

The nuclear spindle remains entirely distinct from the centrosomes and astral systems. Its fibres do not converge at a special point at each pole, but end free in the cytoplasm, the poles of the spindle thus being truncate. *Each mantle fibre, however, points directly toward the centrosome.*

The distinction between nuclear substance and cytoplasm may be readily seen up to the late anaphase of the first division.

The second division follows very closely on the first. The centrosomes separate and move apart upon the cell membrane, forming a spindle similar to that of the first spermatocyte.

The first maturation mitosis results in a longitudinal or equation division of the chromosomes, while the second is the reduction division. Evidences of this are seen in the sequence of cleavages in the prophase, in the attachment of the mantle fibres during the metaphase of the first mitosis, in the shape of the daughter chromosomes during the anaphase and telophase of the first division, and in the shape of the dyads and their position in the equatorial plate of the last division.

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Explanation of Plates.

All drawings were made with the aid of a camera lucida. A Leitz $\frac{1}{12}$-inch homogeneous immersion objective and No. 4 ocular were used, producing, at the projection distance employed, a magnification of 1280 diameters. All figures were reduced $\frac{1}{3}$ in reproduction, making a final magnification of 820 diameters.

PLATE 1.

Figure 1. Spermatogonium of *Lithobius mordax* in the "resting stage." Each nucleus possesses two karyospheres, which contain all of the chromatin of the cell.

Figure 2. Prophase of spermatogonium of *L. mordax*. The chromosomes have arisen from the karyosphere, and are distributed throughout the nucleus in the form of fine granular threads. The nucleoli and the accessory chromosome are all that remain of the karyosphere.

Figure 3. Early spermatocyte of *L. mordax*. The chromosomes have undergone pseudo-reduction. The massing of the chromosomes about the accessory chromosome to form the karyosphere has already begun.

Figure 4. *Lithobius sp.* ? at about the same stage as is shown in Figure 3. Here the nucleoli serve as the basis of the karyosphere. Two nucleoli are seen, one of which is already acquiring chromatin.

Figures 5, 6, 7. *First* spermatocytes of *L. mordax* in the early growth period, showing massing of the chromosomes to form the karyosphere. The outlines of many of the chromosomes can still be seen.

Figure 8. Later stage of growing *first* spermatocyte of *L. mordax*. The karyosphere has increased in size, is becoming more regular in outline, and stains less deeply, owing to the acquisition of nucleolar material. The nucleus also contains diffuse deposits of achromatic material. The outlines of some of the chromosomes are still to be seen.

Figure 9. Nucleus of *first* spermatocyte of *L. mordax* in the vesicle stage, showing the presence of both chromatin and nucleolar substance.

Figure 10. The vesicle stage in *L. mordax*, showing characteristic shape of cell, dense structures of the cytoplasm, and characteristic appearance of the nucleus. The karyosphere appears entirely black, and is surrounded by a mantle of non-chromatic material.

Figures 11, 12. Nuclei of *first* spermatocytes of *L. multidentatus* in the vesicle stage. The amount of chromatin is here less than in L. mordax. It is spread out over the surface of the nucleolus, forming a karyosphere similar to that of Scolopendra subspinipes. The achromatic deposits are confined to several dense masses.

Figure 13. Very early prophase of *first* spermatocyte of *L. multidentatus*. The chromatin in the karyosphere is becoming more loosely arranged. The deposits of achromatic material have broken up into a number of smaller masses.

Figures 14–17. Nuclei of spermatocytes of *Lithobius sp.* ? in the vesicle stage. Two or more karyospheres are usually present, each containing considerable nucleolar material.

FIGURE 18. Nucleus of *first* spermatocyte of *Lithobius sp.* ? in early prophase. Most of the chromosomes have left the karyosphere, and are in the form of granular segments.

FIGURES 19^a, 19^b, 19^c, 20, 21. Later prophase of *first* spermatocyte in *Lithobius sp.*?, showing various stages in formation of the tetrads and in disintegration of the nucleoli. Figures 19^a, 19^b, and 19^c represent successive sections of the nucleus of one cell.

FIGURE 22. Mid-prophase of *first* spermatocyte in *Lithobius sp.* ? The tetrads have contracted to form denser bodies of chromatin.

FIGURE 23. Nucleus of *first* spermatocyte, showing early stages in the formation of the tetrads in *L. mordax.* Some of the chromosomes have undergone longitudinal splitting, resulting in double rows of globules. Others are already taking on the form of characteristic tetrads. One chromosome is just arising from the karyosphere. The nucleolar material is already becoming vacuolated.

FIGURES 24, 25. Mid-prophases of the *first* spermatocyte of *L. mordax.* The centrosomes are moving apart along the inner face of the cell membrane. The fusion of the globules forming each chromatid of the tetrad has begun. In two chromosomes in Figure 25 this fusion is complete, there being only four parts to the tetrad. The nucleolus is much reduced in size.

PLATE 2.

FIGURES 26, 27. Late prophase of first spermatocyte of *L. multidentatus.* Many of the tetrads have already become homogeneous. However, the dividing planes are still very evident. The linin fibres are being converted into definite threads.

FIGURE 28. Late prophase of *L. mordax.* The nuclear membrane has disappeared, and the linin fibres are becoming oriented to form the mantle fibres of the spindle.

FIGURES 29, 30. Division figures of the *first* spermatocyte of *L. mordax,* showing the complete independence of nuclear spindle and astral systems. The fibres of the spindle, however, converge toward the centrosomes. The distinction between nuclear sap and cytoplasm is very distinct. The chromosomes are arranged in an equatorial plate. At the point of attachment of the mantle fibres to the chromosome, a small, darkly stained body is seen.

FIGURE 31. Chromosomes seen in a single equatorial plate of *L. mordax* showing the variety of shapes and sizes and the manner of attachment of the mantle fibres.

FIGURE 32. Mid-anaphase of *first* spermatocyte of *L. mordax.* The daughter chromosomes are of a distinct dumb-bell shape, the constriction representing the plane of the second division.

FIGURES 33, 34. Later stages in division of *first* spermatocyte of *L. mordax.* Where chromosomes can still be distinguished, their form is unchanged.

FIGURE 35. Late telophase of *first,* or early prophase of *second,* spermatocyte of *L. mordax.* Chromosomes still dumb-bell shaped. Centrosomes are moving apart along inner surface of cell membranes.

FIGURE 36. Metaphase of *second* spermatocyte of *L. mordax.* Achromatic structures similar to corresponding stage of first division. The dumb-bell shaped chromosomes are arranged with the constriction in the plane of the equatorial plate.

FIGURE 37. Telophase of *second* spermatocyte of *L. multidentatus.*

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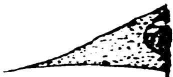
PLATE 1.



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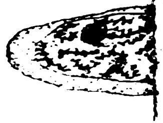

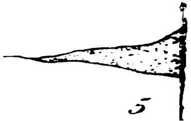

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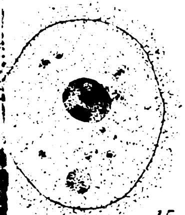

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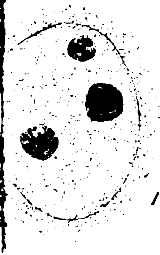

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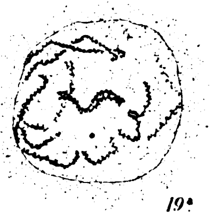

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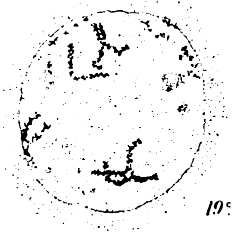

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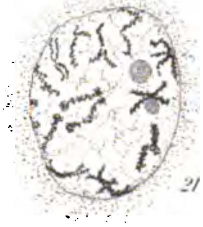

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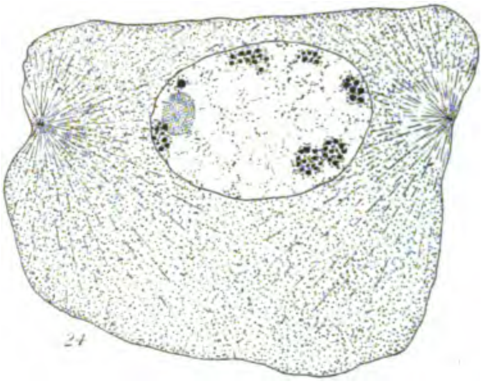

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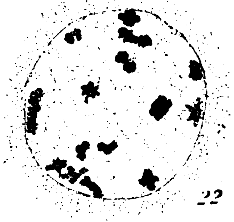

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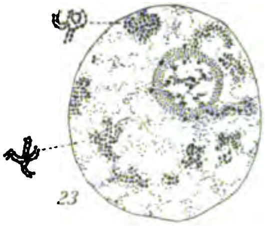

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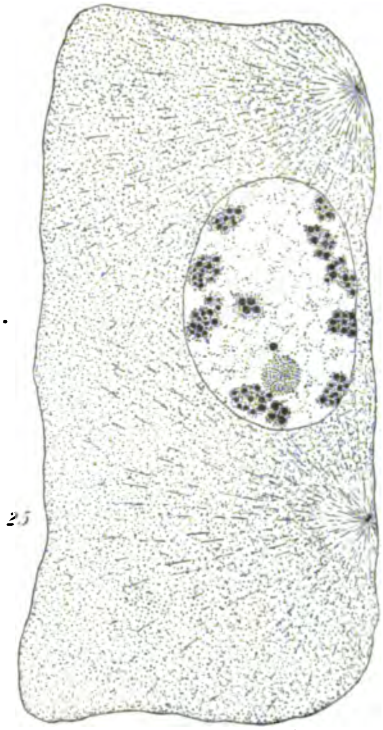
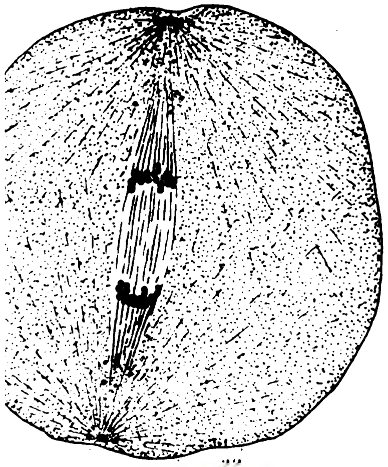


25

B Meisel lith.

PLATE 2.



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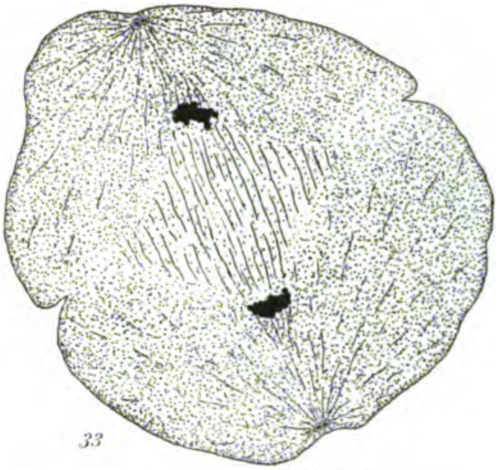

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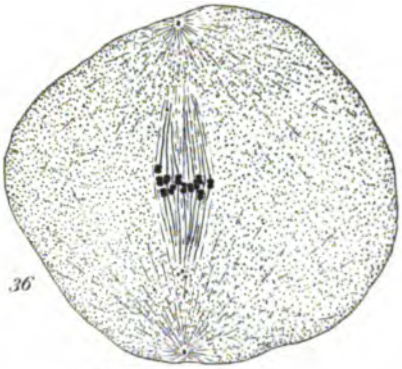

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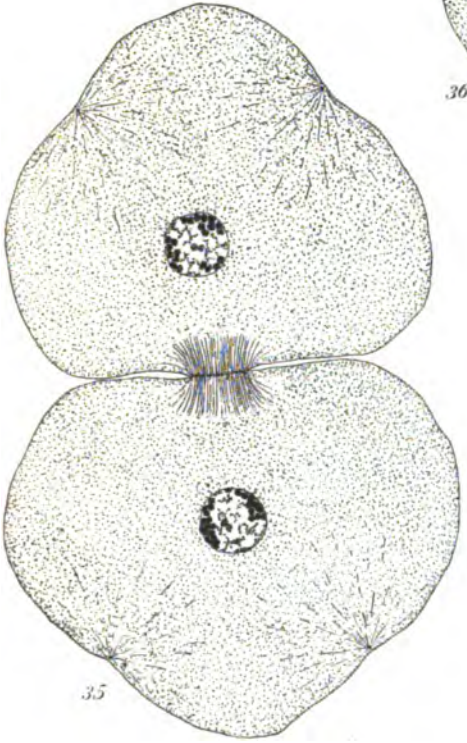

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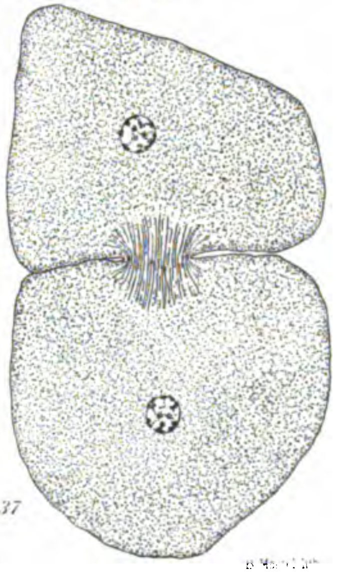

37